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WAR, FAMINE AND PESTILENCE

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THE melancholy tale of famine repeats itself with sinister regularity in the course of man's long struggle both with nature and his fellow man. Throughout recorded history, floods, drouths, earthquakes, frosts, blights and plagues of insects have shown their devastating power from time to time to cause famine and its accompanying pestilences. Furthermore, man himself, by his economic maladjustments, strifes and wars, creates additional conditions which also lead to want and hunger. But no matter how famine may be caused, pestilence, its faithful friend, stands always by, ready to add to the cauldron of misery a varied assortment of infectious agents which, in individuals or in multitudes, can destroy most quickly their devitalized and less-resisting victims.

Abraham Lincoln once said that God must love the poor because he makes so many of them. It might likewise be said that man must love disease because he makes so much of it. Although disease has always taxed the utmost powers of human ingenuity, human beings, nevertheless, continue to create new maladies almost as rapidly as they learn to conquer older ones. A host of man-made diseases—alcoholism, vitamin deficiencies, industrial disease, social strife, poverty, war—all testify to man's unwillingness to learn the costly lessons of the past. Is it any wonder, therefore, that man-made famines follow so frequently the recurrent cycles of depressions and of war?

The term famine is usually applied to the condition of a marked dearth of food; there are, of course, degrees of dearth, and individuals fortunate enough to possess some wealth can frequently get food or else flee from the famine area. This ability to buy food on the part of some, however, tends to increase the scarcity for others; in other words, the buying power of the few forces up the prices for the many, thus making the burden on the poor more severe. In Germany in World War I this sequence led to disaster and caused, in part, the final collapse. Due to governmental errors in the control of the limited food-supplies whereby farm prices were fixed while wages were not, illegal selling of food soon led to the development of the pernicious system of "schleich-handel," today's "black market." It has been estimated that near the close of the war from one quarter to one third of the Germans' food supply consisted of smuggled goods. But inasmuch as the poor, under such circumstances, are powerless either to buy enough food, due to steadily rising prices, or to escape from the area of famine, they constantly grow poorer. Soon fear and hunger become more urgent and panic hurries them along, first to spiritual and later to physical deterioration.

The paramount fact in famine, there-

fore, is poverty, which, if not relieved, leads inevitably to disaster. As Geddes Smith has aptly said, "There can be no doubt that the bitter bread of poverty is seasoned with disease and early death." For example, it is well known that the death rates from tuberculosis and pneumonia vary inversely with the economic state; and surveys made some years ago showed that the morbidity rates from pneumonia were twice as high in people on relief as in those with comfortable family incomes. The same trends also apply to tuberculosis (Smith). Walford has pointed out that nearly all the great epidemics of typhus have occurred during seasons of scarcity and want and that "whatever may have been the cause of the scarcity, it has been a common observation in many epidemics that the fever has raged among the poor in a degree proportionate to the privations they have endured. It was especially observable during the Irish potato famine: those persons who had been reduced by insufficient food were invariably attacked." It is apparent, therefore, that famine and poverty serve as faithful handmaidens to pestilence itself.

Great famines have played a dominant part in shaping many of the events of history and few countries have escaped their moulding influences. Two thousand years before the birth of Christ recurrent famines, due to failure of the Nile to flood, reduced the civilization of that time to the lowest levels of human degradation; since then fearful famines have occurred in India, Russia, England, Ireland, Europe, China and Egypt and it has been said (McKinnon) that during the first seventeen centuries of the Christian era famine occurred somewhere nearly every eight years, accompanied by pestilence almost every five.

In all these famines poverty, hunger and fear combined to liberate the evil forces manifested so frequently in murder, robbery, suicide and revolution. For example, in some of Egypt's early famines social strife quickly dominated the scene, and revolution led to counter-revolution as slaves turned on their masters and citizens organized to kill the slaves. Peasants refused to till the fields for fear of being murdered, thus adding to the dearth of food. In a famine portrayed in the second book of Kings cannibalism is described. In fact in all countries where famines have been unusually severe human flesh has been eaten, and not infrequently graves have been opened for their food. The Roman Empire suffered frequently, and in one famine thousands of desperate people are said to have drowned themselves in the Tiber because of the pangs of hunger. In England in the year following the battle of Hastings, William the Conqueror devastated the eastern coast so that "no hold might remain for any future invasion of the Danes. Harvest, cattle, the very implements of husbandry were so mercilessly destroyed that the famine which followed is said to have swept off more than a hundred thousand victims, and half a century later the land still lay bare of culture and deserted of men." Again in England some centuries later the devastation following the Black Death so reduced the normal supplies of labor that "harvests rotted on the ground and the fields were left untilled, not merely from scarcity of hands, but from the strife which now for the first time revealed itself between capital and labour." In Ireland, in the eighteenth century, depressions and attendant poverty led to "want and misery on every face . . . the roads spread with dead and dying bodies, mankind the color of the docks and nettles which they fed on . . . the universal scarcity was followed by fluxes and malignant fevers, which swept off multitudes of all sorts, so that whole villages were laid waste."

Of Russia in recent years Gantt says: "The famine of 1920–21 was probably by

far the worst in the history of Russia. Dogs, cats, horses, camels, rats, roots, berries, earth, dung, corpses were eaten, and the author knew of cases of human meat being sold in the market, and of people killing their sisters, brothers, parents and children for food. In Samara the insane asylum housed chiefly cannibals. Cities were sometimes reduced to one third or one half by famine and epidemics."

These tragic hungers, fearful as they were, seem merely "curtain raisers" to the world-wide drama unfolding in the total war which now affects all nations. To-day the specter of famine struts across the stage more boldly than in former wars, as to the forces which engender poverty and scarcity of food is added the impossibility of escape for many. Modern war attempts, by sinkings from beneath and on the sea and by bombs and fire from the sky, to bring stark famine to the enemy and thereby break his will to fight. In this grim struggle slight protection can be afforded women, children and non-combatants; in fact, if soldiers are to be fed, non-combatant populations, particularly those in conquered countries, must suffer most of all. Infectious disease, therefore, becomes much more than a problem of germ-transmission. It becomes, instead, more complicated, and its development is subject more and more to the determining influences of malnutrition which tend to deprive the body of the customary means of resisting infectious processes that are ordinarily well-borne. Moreover, famine usually is made worse by devitalizing fatigue as starving individuals strive as long as possible to secure the food essential for their survival. If, also, they must endure slavery while working for their captors, inevitably the time will come when famine and pestilence will take over where war leaves off. And when that time comes, again it can be truly said that "Grim, gaunt and loathsome, like the three fateful sisters of Greek mythology, war, famine and pestilence have decreed untimely deaths for the hosts of the earth. . . . A veritable trinity of evil, the three are as one scourge, equal in their devastating power and in their sinister universality" (Graves).

The constant association of this "evil trinity" is not surprising in view of wars' disruption of the normal modes of life. The assemblage in intimate relationships of large groups of young men, the manifold exposures to the elements and to one another with the resultant opportunities for the transmission of infectious agents from person to person, either directly or from increasingly concentrated air contamination, all furnish abundant opportunities for "herd infection." Moreover, the disorganizations of civilian life, excessive taxation and the loss of crops and commerce involve every one in the generalized confusion. Inevitably there follow scarcities of food supplies, physical hardships, exposure to fatigue and to unsanitary ways of living, all of which may tend to lessen resistance to infectious disease. It is because of these effects, therefore, that in the past as epidemics of typhus, cholera, typhoid fever and relapsing fever followed famine they earned the names of "famine fevers."

It is true that in many of the former wars the pestilences affected mainly the armies in the field, as seen, for example, in the epidemics of typhus and typhoid fever among Napoleon's troops on their retreat from Moscow. But more disastrous was their effect upon civilians as these soldiers spread disease both on the route from Russia and after their return home. Indeed Clark says that "the most serious human cost of war has been not losses in the field, nor even the losses from disease in the armies, but the losses from epidemics disseminated among the civil populations. It was the war epi-

demics and their sequelae, rather than direct military losses, that accounted for the deep prostration of Germany after the Thirty Years War."

Of all former wars this war (1618–48) affords perhaps the closest analogy to the present conflict. In it all Europe was a battlefield on which civilians suffered more than combatants as famine and pestilence took their heavy tolls. Prinzing, in fact, divided it quite simply into two main periods, the typhus period and the plague period. Major says that at the close of this long struggle,

> the picture of desolation, famine, disease, death, confusion and anarchy presented by Central Europe resembled the chaos which followed the downfall of the Roman Empire . . . in Germany the cities had become depopulated and fallen into decay; the countryside, with its cultivators dead, became a dreary desert. The churches were destroyed or empty, with their priests dead or dispersed. The schools and universities had disbanded, their teachers killed or scattered to the four winds. The libraries and museums, repositories of centuries of learning and culture, had been destroyed. Central Europe has no blacker page in its long history of travail and suffering. . . . It would be pleasant to record that some nuggets of pure gold had been drawn from the consuming fire of the Thirty Years War, but the search has been fruitless. The contemporary historians' writings record only a melancholy story of plunder, pillage and pestilence. Their pages are filled with accounts of pestilence, scenes of horror and death, epidemics sweeping the cities and countryside, unchecked by any medical discoveries, dying down only for lack of victims. . . . The effects . . . in Germany were felt for several generations. While the scientists of England, France, Holland and Italy were making the astonishing discoveries that mark the seventeenth century as a turning point in the history of science, depopulated and devastated Germany was rebuilding her destroyed cities, reclaiming her desert lands and trying to regain some vestiges of a civilization destroyed by thirty years of incessant warfare. The war had made a desert not only of their country but of their minds as well.

The description of this widespread chaos makes one wonder if indeed it is a preview of the coming years. The achievements of modern medicine seem almost futile when confronted with such devastation. Universal misery, famine and destitution can largely nullify all efforts to prevent dissemination of disease when, with water supplies polluted, with lice and rats breeding in the ruins of bombed cities, with scanty fuel rations, with clothing inadequate for cold winters and with gnawing hunger imminent, people gradually lose the incentives to observe the simplest rules of hygiene. When to these factors are added severe malnutrition and despair, the record of the Thirty Years War may once again become a familiar story in many European homes.

One of the tragedies of the present war lies in the fact that so many are now engaged throughout the world, and all with patriotic fervor, in tearing down those structures conceived and erected by some of the world's great minds in an effort to eliminate the disastrous consequences of infectious disease. The conquest of infection is a task in which all nations have had a share, and such names as Pasteur, Roux, Ehrlich, Behring, Koch, Metchnikoff, Jenner, Lister, Shiga, Kitasato, Smith and Ricketts illustrate the efforts of kindly men to conquer and control the ravaging pestilences of mankind. Because of them the science, immunology, arose, and through its influence in a few short years infectious disease has lost much of its terror. Of these, Churchill's tribute might be paraphrased, for never in the field of human endeavor was so much owed by so many to so few. Certainly within the past few decades more has been accomplished in the prevention and control of infectious disease than in all the centuries before. Such diseases as rabies, smallpox, typhoid fever, typhus, diphtheria, scarlet fever, plague and tetanus no longer call forth the dread once associated with their names. Improvements in the art of immunization based on procedures developed in the past half-century have made possible the protection of large populations, both in military and in civil life.

Resistance to infectious disease depends upon defensive mechanisms either inherited or acquired. To some diseases man is naturally immune, just as there are human diseases to which the lower animals are resistant. Under normal conditions many kinds of bacteria, viruses and animal parasites are unable to overcome these defensive mechanisms, but resistance to them, nevertheless, is always limited, and only slight environmental changes may, at times, disturb the delicate balance between susceptibility and resistance.

The phenomena of acquired resistance are perhaps better understood than are those of natural resistance, and they certainly are more relied upon in the handling of infectious disease. Upon them depend the powers of public health departments and of armies to operate confidently in preventing the spread of communicable disease. Although the basic facts of acquired resistance are so well known, details secured within recent years have helped to demonstrate further both the potentialities and limitations of this defensive mechanism. A brief consideration of one aspect of acquired resistance may serve to clarify to some extent its complex relationships to many latent infectious processes which in wartime may flare up into severe pestilences.

Bacterial infection, looked at from a general point of view, is in its beginning in most instances a local process; that is, the microorganisms, if they are to induce disease, must first penetrate the external barriers of the body and begin to multiply. If they are unable to grow in their new environment they soon succumb; if, on the other hand, they grow and spread, they may disseminate to vital areas where ultimately they may cause a lethal outcome. It is obvious, consequently, that upon the microbe's ability to grow depends its adverse effects; the question of microbic growth, therefore, occupies the foreground of the general problem of infection and resistance. In bacterial infection, Time plays a commanding role: It is as important in an incipient infection as it is in a beginning forest-fire; for obviously, if conditions can be so controlled that bacteria, after entering the body, are compelled to remain localized at or near their portal of entry, in tissues unfavorable for bacterial growth, many of the dangers of acute infection will be removed.

Within the past few years much progress has been made in the understanding of the process of bacterial growth in early infectious lesions. By the production in experimental animals of so-called "model infections" it has been possible to observe through the microscope what actually happens in an area of beginning infection and to demonstrate how the development of an infective lesion can be controlled. For example, it has been learned that bacterial growth in normal tissues differs markedly from the growth in immune ones. In the latter the initial microbic growth is sparse and more circumscribed, and the inflammatory reaction is intensified and more effective. This fact is now well known and has been amply demonstrated with several kinds of pathogenic microorganisms and in different species of animals. One example will be given here, chosen because the facts are so well attested and so easily revealed.

The normal rabbit is extremely susceptible to infection with the pneumococcus. This fact is of particular significance because it affords an opportunity to study the early lesions sequentially in an infection which almost invariably leads to a lethal ending. This type of infection resembles in some respects, therefore, and particularly in its ultimate effects, infection of the human being with a virulent strain of the plague bacillus. Indeed some strains of the pneumococcus are so virulent and can

grow so readily in the rabbit's tissues that as few as four microorganisms, if injected into the skin, will kill within two days.

From careful microscopical studies of this so-called pneumococcic dermal lesion we know that the microorganisms grow freely in the tissues near their point of entrance, spread widely and rapidly to the body as a whole, and kill the animal by an overwhelming blood-stream infection. This "model infection," therefore, combines the conditions of absolute susceptibility of the host and unusually effective parasitic adaptability of the pneumococci. And yet, by a very simple immunologic device, *viz.*, immunization with dead pneumococci or injection of specific anti-pneumococcal serum, the native susceptibility of the rabbit can be changed into such a high degree of resistance that hundreds of lethal doses of virulent pneumococci can be injected with impunity. Microscopical observation reveals the significant fact that the immediate immune reaction so affects the pneumococci as to stop their growth and spread through the contiguous tissues. Immune bodies specific for the pneumococci, cooperating with the phagocytes, achieve the objective of acquired resistance, thereby converting a state of complete susceptibility into one of high resistance.

Acquired resistance, therefore, whether it has been attained by artificial immunization or after recovery from an earlier infectious process, manifests itself primarily by an enhanced capacity to prevent the later development of infection of a similar type. This capacity, moreover, depends in large measure upon the effective action of specific antibodies. The nature of these antibodies has been for many years an unsolved problem because of doubt concerning their chemical composition. Within the past decade, however, this problem has been solved. Chemical investigations have revealed the fact that antibodies are molecules of a body-protein, globulin, which has been specifically modified during its synthesis by contact with antigen. The demonstration of this fact unquestionably marks one of the important mile-stones in the field of immunology and is to be compared in significance to the recent chemical discoveries of the carcinogenic hydrocarbons which have had such an important influence upon the study of cancer.

Proof of the chemical composition of antibodies having thus been finally accomplished, it soon became apparent that their continued production within the tissues depends upon the latter's ability to synthesize globulin. This synthesis, in turn, requires the adequate intake of proteins in the food; in other words, food-proteins with a full complement of amino acids are essential both for the fabrication of normal globulin and of antibody-globulin. Diet, therefore, assumes a more significant role in acquired resistance than has hitherto been realized. Carbohydrates, minerals, fats and vitamins, regardless of their importance in the bodily economy, can not replace amino acids essential for globulin production; in other words globulin can not be constructed without protein "building stones" any more than masons can build with mortar only but without an adequate supply of bricks.

These facts assume a larger significance now that proof has been established that prolonged severe protein-starvation leads progressively to the depletion of the body's protein reserves from which both normal globulin and antibody-globulin are formed. Experiments in progress show, moreover, that animals so depleted lose the capacity to produce antibodies as abundantly as do well-nourished animals. The capacity of a protein-depleted animal to form antibodies normally can be again restored, however, by the rebuilding of the body's

protein reserves through the addition to the low-protein diet of a mixture of amino acids.

The relationship of food-intake to antibody-production becomes increasingly important to-day, for in a time of total war the protective potentialities of acquired resistance tend to undergo deterioration. And upon this deterioration may depend the fate of nations when they approach the abyss of imminent catastrophe as incipient infections begin to gain in strength and vigor. Such augmentation of microbic virulence may arise not only because of better opportunities for germ-transmission but also because starvation and fatigue, by their devitalizing action, may decrease the power of acquired resistance to function effectively.

Several facts may be cited foreshadowing these sinister eventualities; some, indeed, have already been alluded to with respect to the wars and famines of the past. More recent, however, is the evidence indicating the major roles played by starvation and disease in the termination of World War I. Although the Nazis wish to believe that that conflict ended because of trickery by their foes, there is abundant evidence that the year 1918 revealed to Germany and to Europe the colossal power of famine and pestilence to dominate rulers, generals and councils of war. Although the present war has not as yet reproduced the widespread miseries of 1918, except in the captive countries, fragmentary reports are already filtering through that tuberculosis is once more on the increase in Germany and that throughout Europe typhus, typhoid fever, cholera and other scourges may not be far behind. These diseases may, for a time, be kept in check, but it will be no surprise if, as in World War I, malnutrition, poverty and pestilence once more find a common rendezvous. Armies have altered the map of Europe before only to find themselves powerless to escape from the relentless grasp of famine and pestilence. Napoleon captured Moscow, but, when lack of food forced him to retreat, typhus and enteric disease soon made the *grande armée* a pitiable mass of panic-stricken, starving, dying refugees.

It is now well known that during World War I the death rate from tuberculosis increased throughout Europe and that by 1918 it had doubled in Germany. The fact is all the more significant because this death rate up until 1914 had been dropping steadily throughout the world; by 1918, however, it had risen again in Europe to a point about 25 per cent. higher than in 1914.

In attempting to ascertain the causes of this formidable rise the possibility of housing shortages and the resultant overcrowding came to mind, but observers soon pointed out that the rise in the mortality rate had preceded the housing shortage. Attention then was centered on the shortage of food, particularly fats and proteins. Furthermore, in Denmark the death rate from tuberculosis, although rising early in the war, dropped sharply in 1918. The probable explanation is that, as the food blockade in 1917 became more effective, the elimination of food exports forced the Danes to consume their own vast supply of dairy products. Moreover, the tuberculosis death rate continued to decline after the war, although Denmark had a serious housing shortage at that time.

In the present conflict, as in World War I, the slogan "Food Will Win the War" still plays an important and perhaps a dominant part in military strategy. Morale, the objective of all propaganda, may be sustained for months or even years by shrewd suppressions and distortions of the news, but no morale can be nourished indefinitely when suckled on the withered breast of hopeless and devitalizing hunger. Starvation will lead in time to lowered morale as

families sicken and die from infections which could be well tolerated in normal times. And always in the background lurks the danger that, as infectious agents pass more quickly from person to person under these conditions of decreased resistance, the possible exaltation of microbic virulence or the increasing concentrations of infective agents may lead eventually to the setting-off of fearful epidemics. No one knows just how these world-wide epidemics start, but we know from World War I what happened when influenza, typhus and cholera swept over large parts of the world. In the fourteenth century the Black Death which caused the deaths of about one half of the peoples of Europe followed, according to one suggestion, a fearful famine in northern China.

During the first World War famine brought into prominence a form of malnutrition whose importance had hitherto been largely underestimated. As starving peoples throughout Europe were forced to subsist on foods of low protein values, particularly potatoes, turnips, leafy plants and salty soups derived therefrom, large numbers of them, especially when performing hard labor, became dropsical. Furthermore, physicians reported that many of these patients manifested a markedly increased susceptibility to infections of various sorts. This condition had long been known under a variety of names, the most common being war edema. Observers looked vainly for the cause; although many suspected that it had a nutritional basis, attention centered largely around the idea that it was due to a vitamin inadequacy. Not until near the end of the war was the real cause determined; in 1918 two American physiologists, Miss Kohman and Miss Denton, demonstrated conclusively that the edema was due essentially to a deficiency of protein in the diet. When rats were fed on a diet low in protein but with adequate amounts of carbohydrate, fats, vitamins and salts, the edema appeared; its elimination was accomplished solely by the addition to the diet of a sufficient amount of protein (casein). As Dr. A. J. Carlson remarked at the end of the war: "After observing and studying war edema throughout Eastern Europe I returned to find that the cause had been discovered in my own laboratory." Since then these experiments have been abundantly confirmed and we know now that the edema is due to the lowered protein content of the blood, the consequence of a prolonged low protein diet. When the protein levels of the blood fall below a certain value, referred to as the "edema level," fluids tend to accumulate in the tissues because the lowered osmotic pressure of the blood can no longer prevent this transudation.

It is not surprising that in these states of hypoproteinemia there should be a lowered resistance to infectious agents because of an inability to synthesize antibody-globulin as effectively as in normal times.

The gradual depletion of the supplies of protein-rich foods in Europe under the circumstances of modern war seems almost inevitable. Although reliable information is not available, there can be but little question that the shortage of fodder must have led already to serious restrictions in the production of meat animals and of milk and dairy products. A gradual diminution in the supplies of fish, fowl, meat, cheese and eggs will lead necessarily to greater reliance upon vegetables, particularly potatoes (which contain only two per cent. protein) and to other vegetables of lower protein values. This war has been so planned and executed thus far by Germany that the first to suffer are the captive nations whose food resources have been "levied" and transported to Germany. There can be but little doubt, therefore, that starvation will reap its biggest harvest in

these conquered countries. Reports from Greece already tell of thousands dying from starvation, particularly infants and young children who can get but little if any milk, and similar events are doubtless happening elsewhere throughout conquered Europe. However, the fact remains, so far as Germany is concerned, that food and livestock once confiscated can not be levied upon again with equal profit. The gradual deterioration of the food supply throughout all Europe can lead but in one direction; and Europe is now in its fourth war winter. Furthermore, the time may not be far away when Germany will no longer hold these countries from which so much food is now confiscated. When that time comes, the real effects of famine inside Germany may quickly become more apparent.

Continued emphasis upon the importance of acquired resistance seems to be particularly warranted in the present war because infectious disease treats all alike. No longer is infection's harm restricted primarily to the fighting troops; the workers on the farms and in the factories are of increasing value to the military effort and their health becomes of prime importance. If, therefore, they succumb to infectious agents because of privation, cold, fatigue and hunger, the war effort will inevitably deteriorate. Such infections do not mean necessarily those commonly looked upon as war-time pestilences, but rather the so-called minor infections so commonly taken more or less lightly. Thus, "colds," bronchitis, mild pneumonias, diarrheas, pharyngitis, wound infections and the childhood diseases—measles, whooping cough, scarlet fever and diphtheria—which usually are not characterized by high death rates may become definitely more menacing. For example, Prinzing, in commenting on the effects of the siege of Paris of 1870, says:

> Insufficient nourishment is seldom the direct cause of death; on the other hand, it frequently so weakens people that they are much more subject to sickness, or, if they have already contracted some disease, they are much more likely to die, or, if they recover, to convalesce slowly. Thus Vacher states that typhoid fever, which usually results fatally in one out of four cases, during the siege of Paris carried away no less than forty per cent. of those who contracted it; tuberculosis, he says, often acquired an acute form and caused death within a few weeks. Little children present slight resistance to famine.

The implications of these facts in severe starvation are obvious. Although the depletion of the body's protein reserves is gradual and may not take on alarming proportions for months or even years, nevertheless it will develop insidiously when one is compelled to live energetically and to work laboriously under conditions of exposure to fatigue and cold on an inadequate protein-intake. Furthermore, due to the fact that the protein foods are the most expensive kinds, and even if available, can not be purchased by people in countries whose currencies have been debased, poverty once more dominates the famine-picture, particularly in the occupied countries of Europe. No doubt the Germans entered this war with larger food reserves than in 1914, but it should be recalled that for many years their policy of guns before butter has had some effect upon the overall nutritional picture of the German civilians. Only the future can reveal the long-time effects of such food-restriction, but it is apparent that the ideas of "blitzkrieg" and "vielejähinge krieg" are diametrically opposed. From now on the difficulties in replacing farm machinery will become greater, and with more and more persons thrown into the combat lines in Russia and elsewhere, the ability of old men, women, children, cripples and prisoners of war to grow the food will become more difficult. And even when produced the increasing strain on transportation is bound to tell in a protracted war.

Out of these famines, wars and pesti-

lences it is to be hoped that at least some human progress may have been achieved. Although too frequently only psychopathic manifestations dominate the historical scene, there is no doubt but that in some instances human welfare has been advanced. Although the Black Death killed its millions, in England it was followed by the Peasants' Revolt, which accelerated the break-up of the large estates and the development of industry by the enlarging middle class. In France the many famines caused too often by the excessive taxes imposed by wasteful kings and courts had their eventual aftermath in the Revolution of 1789. Ireland, too, made her general contribution to world-wide progress when the potato famine of 1846 compelled starving millions to emigrate to America. Thus by an irony of fate, America, in compensation for her earlier gift to Erin of the lowly potato, was later repaid by the Irish in person.

Less obvious are the effects of the pestilences when looked at from to-day's point of view. We have seen that in World War I Germany found that empty stomachs do not win wars. This lesson does not seem to have been well learned and events now unfolding may reveal again that the Germans, by depending too much on psychological warfare and blitzkrieg, may have overlooked some important lessons of physiology and pathology. For although it is true that he who lives by the sword may perish by the sword, it is truer still that he who lives by the sword may also perish by the famine and the pestilence.

HEALTH CONDITIONS IN POST-WAR EUROPE

If, in the midst of urgent war effort, justification is needed for the present publication, it is to be found in the fact that during the three years following the last war more individuals died from famine and preventable diseases than were killed in the war itself. This is the more impressive in that the death rate is no measure of the suffering and permanent impairment of health involved. The enormous loss of life was certainly due in part to the existing conditions, many of which were unavoidable, but was also attributable, in a much greater degree, to delay, chaos and the inadequacy of such early relief measures as were undertaken. For over a year after the signing of the armistice, relief work was organized only on the relatively fragmentary scale possible for the limited resources of voluntary bodies. Moreover, the absence of any central coordinating machinery caused serious overlapping, omissions and delay in the acquisition and transport of relief materials and personnel. Though from the beginning the problem was clearly far beyond the financial or administrative scope of private organizations, no central coordinating body was ever created, and more than a year elapsed before government contributions became available on any extensive scale. During this time malnutrition and famine were widespread and steadily increasing, whilst epidemic diseases raged unchecked.

It is only by the creation of a machine ready for immediate operation on the conclusion of hostilities that a similar but more terrible tragedy can be averted. Our obligations to the peoples of occupied countries alone make urgent action a responsibility which we can only properly discharge by careful thought and adequate preparations at the present time. The problems to be considered are many and difficult, but on their wise and rapid solution will depend the lives and health of millions, and the physique and welfare of a generation to come.

At present it is exceedingly difficult to visualize the general reconstruction that will be required in post-war Europe in the spheres of politics, economics and administration, all of which must necessarily be shaped by developments in Europe during the war and after. Medical problems are unlikely to vary in their character with the course of hostilities, and can, even now, be foretold with a reasonable degree of accuracy. Already malnutrition, and in some cases famine, with such resulting diseases as tuberculosis, are widespread over large areas of Europe, particularly Greece and Spain. Typhus fever is now epidemic in most of Eastern and much of Central Europe, as well as in Spain and North Africa. Malaria, too, is increasing. Unless these scourges are quickly combated they will become progressively more extensive as the war goes on, taking their toll of lives and health, including those of the young upon whom depends the future of humanity. As living conditions deteriorate, other diseases will inevitably be added to this group, and the growing shortage of medical personnel and supplies will make it less and less possible for many Governments to take the necessary steps for their prevention and eradication.—*From the foreword, "Medical Relief in Europe," by Melville D. Mackenzie, M.D., The Royal Institute of International Affairs*, London.

PROBLEM OF THE EXPANDING UNIVERSE[1]

By Dr. EDWIN HUBBLE
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I PROPOSE to discuss the problem of the expanding universe from the observational point of view. The fact that such a venture is permissible is emphatic evidence that empirical research has definitely entered the field of cosmology. The exploration of space has swept outward in successive waves, first through the system of the planets, then through the steller system and, finally, into the realm of the nebulae. To-day we study a region of space so vast and so homogeneous that it may well be a fair sample of the universe. At any rate, we are justified in adopting the assumption as a working hypothesis and attempting to infer the nature of the universe from the observed characteristics of the sample. One phase of this ambitious project is the observational test of the current theory of the expanding universes of general relativity.

I will briefly describe the observable region of space as revealed by preliminary reconnaissance with large telescope, then sketch the theory in outline, and finally discuss the recent more accurate observations that were designed to clarify and to test the theory.

THE OBSERVABLE REGION

The sun is a star, one of several thousand million stars which together form the stellar system. This system is a great swarm of stars isolated in space. It drifts through the universe as a swarm of bees drifts through the summer air. From our position near the sun we look out through the swarm of stars past the borders, into the universe beyond.

Until recently those outer regions lay in the realm of speculation. To-day we explore them with confidence. They are empty for the most part, vast stretches of empty space. But here and there, separated by immense intervals, we find other stellar systems, comparable with our own. We find them thinly scattered through space out as far as telescopes can reach.

They are so distant that in general they appear as small faint clouds mingled among the stars, and many of them were long known by the name "nebulae." Their identification as great stellar systems, the true inhabitants of the universe, was a recent achievement of great telescopes.

On photographs made with such instruments, these nebulae, these stellar systems, appear in many forms. Nevertheless, they fall naturally into an ordered sequence ranging from compact globular masses through flattening ellipsoids into a line of unwinding spirals. The array exhibits the progressive development of a single basic pattern, and is known as the sequence of classification. It may represent the life history of stellar systems. At any rate, it emphasizes the common features of bodies which belong to a single family.

Consistent with this interpretation is the fact that these stellar systems, regardless of their structural forms, are all of the same general order of intrinsic luminosity (that is, of candlepower). They average about 100 million suns, and most of them fall within the narrow range from one-half to twice this

[1] Twentieth annual Sigma Xi Lecture, presented in association with the American Association for the Advancement of Science, Dallas, December 30, 1941.

average value. Giants and dwarfs are known, 10 to 20 times brighter or fainter than the average, but their numbers appear to be relatively small. This conclusion is definitely established in the case of giants, which can be readily observed throughout an immense volume of space, but it is still speculative in the case of dwarfs which can be studied only in our immediate vicinity.

The limited range in luminosity is important because it offers a convenient measure of distance. As a first approximation, we may assume that the nebulae are all equally luminous, and, consequently, that their apparent faintness indicates their distances. The procedure is not reliable in the case of a single object because the particular nebula might happen to be a giant or a dwarf rather than a normal stellar system. But for statistical purposes, where large numbers of nebulae are involved, the relatively few giants and dwarfs should average out and the mean distances of large groups may be accurately determined. It is by this method that the more remote regions of space, near the limits of the telescope, may be explored with confidence.

Throughout the observable region we find the nebulae scattered singly, in pairs and in groups up to great compact clusters or even clouds. The small-scale distribution is irregular, and is dominated by a tendency towards clustering. Yet when larger and larger volumes of space are compared, the minor irregularities tend to average out, and the samples grow more and more uniform. If the observable region were divided into a hundred or even a thousand equal parts, the contents would probably be nearly identical. Therefore, the large-scale distribution of nebulae is said to be uniform; the observable region is homogeneous, very much the same everywhere and in all directions.

We may now present a rough sketch of our sample of the universe. The faintest nebulae that can be detected with the largest telescope in operation (the 100-inch reflector on Mount Wilson) are about two million times fainter than the faintest star that can be seen with the unaided eye. Since we know the average candle power of these nebulae, we can estimate their average distance—500 million light-years. A sphere with this radius defines the observable region of space. Throughout the sphere are scattered about 100 million nebulae, at various stages of their evolutional development. These nebulae average about 100 million times brighter than the sun and several thousand million times more massive. Our own stellar system is a giant nebula, and is presumably a well-developed, open spiral. The nebulae are found, as has been said, singly, in groups and in clusters but, on the grand scale, these local irregularities average out and the observable region as a whole is approximately homogeneous. The average interval between neighboring nebulae is about two million light-years, and the internebular space is sensibly transparent.

The Law of Red Shifts

Another general characteristic of the observable region has been found in the law of red shifts, sometimes called the velocity-distance relation. This feature introduces the subject of spectrum analysis. You are doubtless familiar with the fact that in general light from any source is a composite of many individual colors or wavelengths. When the composite beam passes through a glass prism or other suitable device, the individual colors are separated out in an ordered rainbow sequence known as a spectrum. The prism bends the light according to the wavelength. The deflections are least for the long waves of the red and are greatest for the short waves of the violet. Hence position in the spectrum indicates

A SPIRAL NEBULA SEEN EDGE-ON

THIS STELLAR SYSTEM, NGC 4565, IS SO DISTANT THAT NONE OF THE STARS CAN BE SEEN INDIVIDUALLY.

the wavelength of the light falling at any particular place in the sequence.

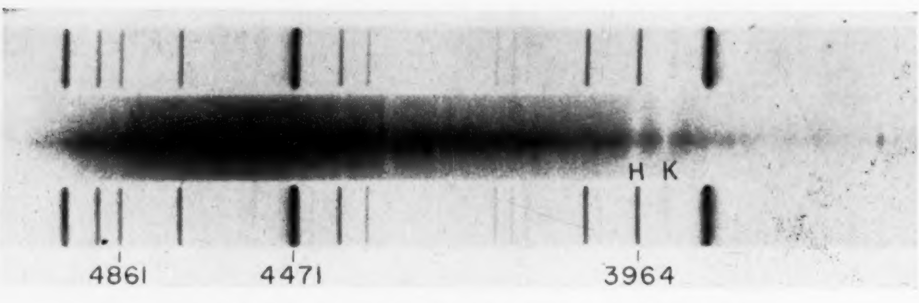
Incandescent solids, and certain other sources, radiate light of all possible wavelengths, and their spectra are continuous. Incandescent gases, however, radiate only certain particular wavelengths, and their spectra, called emission spectra, consist of various isolated colors separated by blank spaces. The patterns are well known; hence gases in a distant light source can be identified by their spectra.

The sun presents a third kind of spectrum known as an absorption spectrum. The main body of the sun furnishes a continuous spectrum. The heavy atmosphere surrounding the main body is gaseous and would normally exhibit an emission spectrum. Actually, the atmosphere, because it is cooler than the main body, absorbs from the continuous background those colors it would otherwise emit. Therefore the solar spectrum is a continuous spectrum on which is superposed a pattern of dark gaps or lines. These dark lines identify the gases in the solar atmosphere and indicate the physical conditions under which they exist.

The nebulae are stellar systems and their spectra resemble that of the sun. Dark lines due to calcium, hydrogen, iron and other elements in the atmospheres of the component stars are identified with complete confidence. In the case of the nearer nebulae, these lines are close to their normal positions as determined in the laboratory or in the sun. In general, however, accurate measurements disclose slight displacements either to the red or to the violet side of the exact normal positions.

Such small displacements are familiar features in the spectra of stars and are known to be introduced by rapid motion in the line of sight. If a star is rapidly approaching the observer, the light waves are crowded together and shortened, and all the spectral lines appear slightly to the violet side of their normal positions. Conversely, rapid recession of a star drags out and lengthens the light waves, and the spectral lines are seen to the red of their normal positions.

The amounts of these displacements (they are called Doppler shifts) indicate the velocities of the stars in the line of sight. If the wavelengths are altered by a certain fraction of the normal wave-



THE SPECTRUM OF THE SPIRAL NEBULA, MESSIER 81

THE SOLAR TYPE SPECTRUM OF THE SPIRAL NEBULA MESSIER 81 IS TYPICAL OF EXTRAGALACTIC NEBULAE IN GENERAL. THE SPECTROGRAM IS REPRODUCED IN NEGATIVE FORM IN ORDER TO SHOW FAINT DETAILS. THE SPECTRUM OF THE NEBULA IS THE BROAD DARK STREAK IN THE CENTER THAT IS CROSSED VERTICALLY BY SOME FAINT LIGHTER LINES, THE ABSORPTION LINES PRODUCED BY THE NEBULA. ABOVE AND BELOW THE SPECTRUM OF THE NEBULA ARE COMPARISON LINES FROM AN ARTIFICIAL SOURCE. THE MOST CONSPICUOUS FEATURE IS THE PAIR OF ABSORPTION LINES (H AND K) DUE TO CALCIUM, WHICH ARE SEEN NEAR THE COMPARISON LINE 3964. MANY FAINT ABSORPTION LINES, DUE TO IRON AND A FEW DUE TO HYDROGEN AND CALCIUM, CAN ALSO BE SEEN, AS WELL AS THE EMISSION LINE 3727, AT THE EXTREME RIGHT. THE LINES ARE SLIGHTLY TILTED BY THE ROTATION OF THE SPIRAL.

lengths, the star is moving at a velocity which is that same fraction of the velocity of light. In this way it has been found that the stars are drifting about at average speeds of 10 to 30 miles per second, and, indeed, that the stellar system, our own nebula, is rotating about its center at the majestic rate of one revolution in perhaps 200 million years.

Similarly, the nebulae are found to be drifting about in space at average speeds of the order of 150 miles per second. Such speeds, of course, are minute fractions of the velocity of light and the corresponding Doppler shifts, which may be either to the violet or to the red, are barely perceptible.

But the spectra of distant nebulae show another effect as conspicuous as it is remarkable. The dark absorption lines are found far to the red of their normal positions. Superposed on the small red or violet shifts representing individual motions is a systematic shift to the red which increases directly with the distances of the nebulae observed. If one nebula is twice as far away as another, the red shift will be twice as large; if *n* times as far away, the red shift will be *n* times as large. This relation is known as the law of red shifts, and it appears to be a quite general feature of the observable region of space.

If these systematic red shifts are interpreted as the familiar Doppler shifts, it follows that the nebulae are receding from us in all directions at velocities that increase directly with the momentary distances. The rate of increase is about 100 miles per second per million light years of distance, and the observations have been carried out to nearly 250 million light years where the red shifts correspond to velocities of recession of nearly 25,000 miles per second, or one seventh the velocity of light.

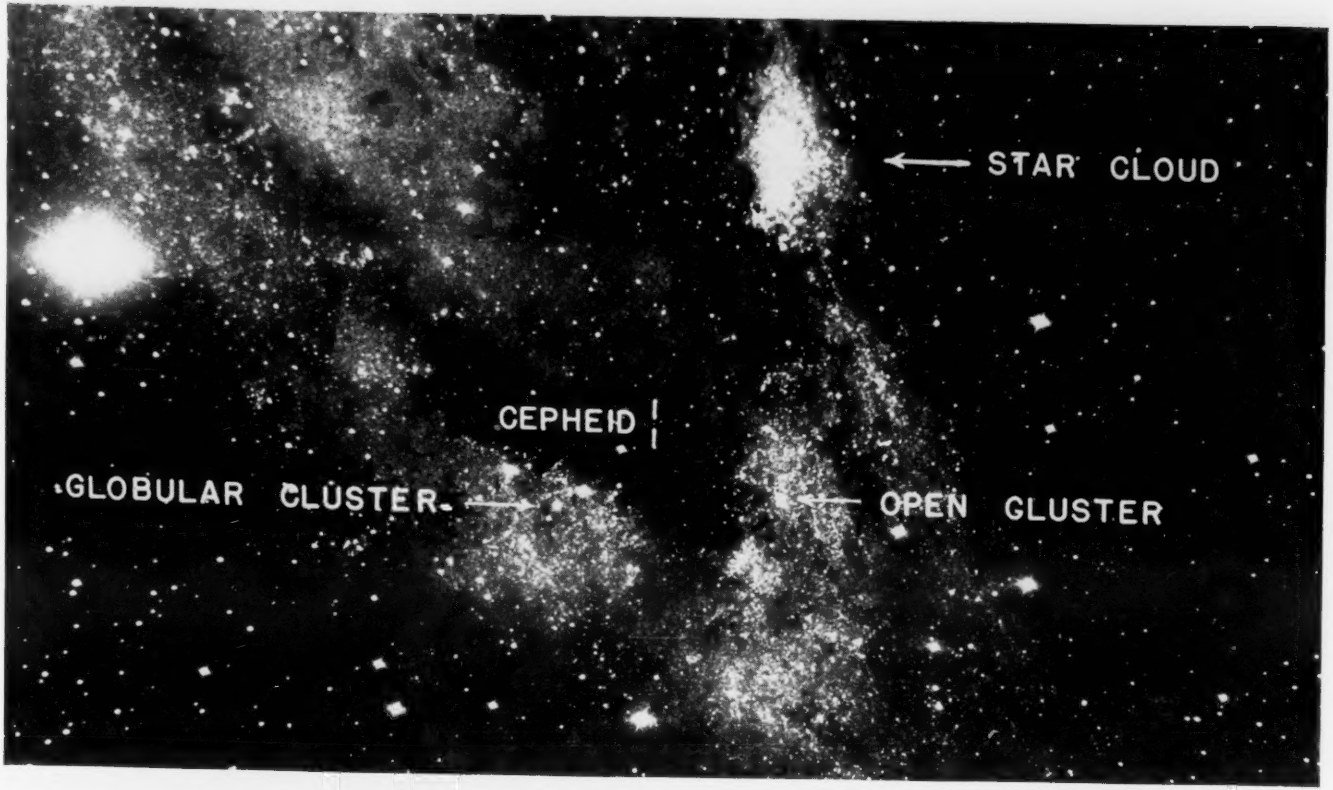
On this interpretation we could account for the present distribution of nebulae by the assumption that all the nebulae were once jammed together in a very small volume of space. Then, at a certain instant, some 1,800 million years ago, the jam exploded, the nebulae rushed outward in all directions with all possible velocities, and have maintained these velocities to the present day. Thus the nebulae have now receded to various distances, depending upon their initial velocities, and our observations necessarily uncover the law of red shifts.

This pattern of history seems so remarkable that some observers view it with pardonable reserve, and try to imagine alternative explanations for the law of red shifts. Up to the present, they have failed. Other ways are known by which red shifts might be produced, but all of them introduce additional effects that should be conspicuous and actually are not found. Red shifts represent Doppler effects, physical recession of the nebulae or the action of some hitherto unrecognized principle in nature.

Cosmological Theory

The preliminary sketch of the observable region was completed about ten years ago. It was not necessarily a finished picture, but it furnished a rough framework within which precise, detailed investigations could be planned with a proper understanding of their relation to the general scheme. Such new investigations, of course, were guided when practical by current theory. Let me explain the significance of this procedure.

Mathematicians deal with possible worlds, with an infinite number of logically consistent systems. Observers explore the one particular world we inhabit. Between the two stands the theorist. He studies possible worlds but only those which are compatible with the information furnished by observers. In other words, theory attempts to segregate the minimum number of possible worlds which must include the actual world we inhabit. Then the observer,



THE NEAREST SPIRAL NEBULA

THE PICTURE SHOWS AN OUTER REGION OF THE GREAT SPIRAL IN ANDROMEDA, PHOTOGRAPHED WITH THE 100-INCH REFLECTOR. THE BRIGHTER STARS CAN BE SEEN INDIVIDUALLY, AND AMONG THEM VARIOUS TYPES CAN BE RECOGNIZED WHICH ARE WELL-KNOWN IN OUR OWN STELLAR SYSTEM. THE APPARENT FAINTNESS OF THESE STARS INDICATES THAT THE DISTANCE OF THE SPIRAL IS ABOUT 700,000 LIGHT YEARS.

with new factual information, attempts to reduce the list still further. And so it goes—observation and theory advancing together toward the common goal of science, knowledge of the structure and behavior of the physical universe.

The relation is evident in the history of cosmology. The study at first was pure speculation. But the exploration of space moved outward until finally a vast region, possibly a fair sample of the universe, was opened for inspection. Then theory was revitalized; it now had a sure base from which to venture forth.

Current theory starts with two fundamental principles, general relativity and the cosmological principle. General relativity states that the geometry of space is determined by the contents of space, and formulates the nature of the relation. Crudely put, the principle states that space is curved in the vicinity of matter, and that the amount of curvature depends upon the amount of matter. Because of the irregular distribution of matter in our world, the small-scale structure of space is highly complex. However, if the universe is sufficiently homogeneous on the large scale, we may adopt a general curvature for the universe or for the observable region as a whole, just as we speak of the general curvature of the earth's surface, disregarding the mountains and ocean basins. The nature of the spatial curvature, whether it is positive or negative, and the numerical value, is a subject for empirical investigation.

The second, or cosmological, principle is a pure assumption—the very simple postulate that, on the grand scale, the universe will appear much the same from whatever position it may be explored. In other words, there is no favored position in the universe, no center, no boundaries. If we, on the earth, see the universe expanding in all directions, then any other observer, no matter where he is located, will also see the universe expanding in the same manner. The postulate, it may be added, implies that, on the grand scale, the universe is homogeneous and isotropic—very much the same everywhere and in all directions.

Modern cosmological theory attempts to describe the types of universes that are compatible with the two principles, general relativity and the cosmological principle. Profound analysis of the problem leads to the following conclusions. Such universes are unstable. They might be momentarily in equilibrium, but the slightest internal disturbance would destroy the balance, and disturbances must occur. Therefore these possible worlds are not stationary. They are in general either contracting or expanding, although theory in its present form does not indicate either the direction of change or the rate of change. At this point, the theorist turned to the reports of the observers. The empirical law of red shifts was accepted as visible evidence that the universe is expanding in a particular manner and at a known rate. Thus arose the conception of homogeneous expanding universes of general relativity.

In such universes the spatial curvature is steadily diminishing as the expansion progresses. Furthermore, the nature of the expansion is such that gravitational assemblages maintain their identities. In other words, material bodies or groups and clusters of nebulae do not themselves expand but maintain their permanent dimensions as their neighbors recede from them in all directions.

Several types of expanding universes are possible, and some of them can be further specified by the nature of the curvature, whether it is positive or negative. In fact, the particular universe we inhabit could be identified if we had sufficiently precise information on three measurable quantities, namely, the rate of expansion, the mean density of matter

in space and the spatial curvature at the present epoch. Recent empirical investigations have been directed toward these problems, and the results will be briefly described in the remaining section of this discussion.

Comparison of Theory and Observations

We may begin with two results which are thoroughly consistent with the theory. The first result concerns the assumption of homogeneity; the second, the conclusion that groups maintain their dimensions as the universe expands.

The distribution of nebulae has been studied in two ways. The first information came from sampling surveys at Mount Wilson and at the Lick Observatory. Small areas, systematically scattered over the sky, were studied with large telescopes. Thus the nebulae that were counted lay in narrow cones penetrating to vast distances. These surveys established large-scale homogeneity over the three quarters of the sky that could be studied from the northern latitudes of the observatories involved.

Later, the Harvard College Observatory, with the help of its southern station, has furnished counts of nebulae extending over large areas but made with telescopes of moderate size. In other words, the nebulae are scattered through wide cones penetrating to moderate distances. Shapley, in his reports, has stressed or perhaps overly stressed, the familiar, small-scale irregularities of distribution, but analysis of such published data as are adequately calibrated agrees with the earlier conclusion. In fact, the mean results from the two quite different methods of study are sensibly the same. This fact re-emphasizes the large-scale homogeneity of the observable region.

The second result is derived from a study of the Local Group. Our own stellar system is one of a dozen nebulae which form a loose group more or less isolated in the general field. These neighboring systems furnished the first clues to the nature of the nebulae and the scale of internebular distances. They are so near that their brightest stars could be recognized and compared with similar stars in our own system. Radial velocities of the members of the Local Group, listed in Table I, suggest that the law of red shifts probably does not operate within the group. This conclusion is positive evidence supporting the validity of the theory. If the universe is expanding, the group maintains its dimensions as the theory requires.

TABLE I
Radial Velocities in the Local Group*

Known members	Observed velocity	Distance in million light years	Expected red shift	Velocity with red shift removed
L M C	+ 45	0.085	+ 13	+ 32
S M C	+ 13	0.095	+ 16	− 3
M 31	− 130	0.7	+ 110	− 240
M 33	− 140	0.7	+ 115	− 265
NGC 6822	+ 20	0.5	+ 85	− 60
IC 1316	− 370	1.3	+ 210	− 580
Fornax	− 40	0.6	+ 100	− 140
Probable members				
NGC 6946	+ 90	1.6	+ 265	− 175
NGC 1569	+ 60	2.3	+ 370	− 310
IC 342	+ 30	2.3	+ 370	− 340

* The observed velocities (second column) represent a more reasonable distribution than the velocities corrected for red shifts (fifth column). The latter are all large and negative with the exception of the first two, for which the corrections are insignificant. This fact suggests that the law of red shifts does not operate within the Local Group.

The remainder of the recently accumulated information is not favorable to the theory. It is so damaging, in fact, that the theory, in its present form, can be saved only by assuming that the observational results include hidden systematic errors. The latter possibility will naturally persist until the investigations can be repeated and improved. Nevertheless, a careful reexamination of the data now available suggests no adequate explanation of the discrepancies.

THE SPIRAL NEBULA, MESSIER 81

THIS STELLAR SYSTEM IS AT A DISTANCE OF ABOUT THREE TIMES THAT OF THE GREAT SPIRAL IN ANDROMEDA, AND ONLY A FEW OF THE BRIGHTER STARS CAN BE SEEN INDIVIDUALLY.

The Interpretation of Red Shifts

The investigations were designed to determine whether or not red shifts represent actual recession. In principle, the problem can be solved; a rapidly receding light source appears fainter than a similar but stationary source at the same momentary distance. The explanation of this well-known effect is quite simple when the beam of light is pictured as a stream of discrete quanta. Rapid recession thins out the stream of quanta; hence fewer quanta reach the eye per second, and the intensity, or rate of impact, is necessarily reduced. Quantitatively, the normal brightness is reduced by a fraction which is merely the velocity of recession divided by the velocity of light—in other words, the red shift expressed as a fraction of the normal wavelengths of the light in question. Recession at one tenth the velocity of light reduces the apparent brightness by 10 per cent.; at one quarter the velocity of light, by 25 per cent.

For velocities of a few miles or a few hundred miles per second, the dimming factor is negligible. But for the extremely distant nebulae, where the apparent recessions reach tens of thousands of miles per second, the effects are large enough to be readily observed and measured. Hence, if we knew the distances of nebulae quite accurately we could measure their apparent faintness and tell at once whether or not they are receding at the rates indicated by the red shifts.

Unfortunately, the problem is not so simple. The only general criterion of great distances is the very apparent faintness of the nebulae which we wish to test. Therefore, the proposed test involves a vicious circle, and the dimming factor merely leads to an error in distance. However, a possible escape from the vicious circle is found in the following procedure. Since we know the intrinsic luminosities of nebulae, their apparent faintness furnishes two scales of distances depending upon whether we assume the nebulae to be stationary or receding. If, then, we analyze our data, if we map the observable region, using first one scale and then the other we may find that the wrong scale leads to contradictions or at least to grave difficulties. Such attempts have been made and one scale does lead to trouble. It is the scale which includes the dimming factors of recession, which assumes that the universe is expanding.

Alternative Forms of the Law of Red Shifts

The project was carried out by the precise formulation of (a) the law of red shifts and (b) the large-scale distribution of nebulae. The form of the law of red shifts is most readily derived from the study of the brightest nebulae in the great clusters. These nebulae, as a class, are the most luminous bodies in the universe, and their spectra can be recorded out to the maximum distances. Furthermore, the clusters are so similar that the apparent faintness of the five or ten brightest members furnishes reliable relative distances. The observations now extend out to about 240 million light years where the red shift is about 13 per cent. of the normal wavelengths of the incoming light. Since the corresponding velocity of recession is the same fraction of the velocity of light, the nebulae in the most distant cluster observed, if they are actually receding, will appear 13 per cent. fainter than they would appear if they were stationary. The difference is small but, fortunately, the measures can be made with fair accuracy.

The results may be stated simply. If the nebulae are stationary, the law of red shifts is sensibly linear; red shifts are a constant multiple of distances. In other words, each unit of the light path contributes the same amount of red shift.

A QUADRUPLE SYSTEM OF NEBULAE

THE THREE SPIRALS, NGC 3185, 3187 AND 3190, TOGETHER WITH THE ELLIPTICAL SYSTEM, NGC 3193, FORM A QUADRUPLET LYING AT A DISTANCE OF ABOUT 7.5 MILLION LIGHT YEARS FROM THE EARTH.

On the other hand, if the nebulae are receding, and the dimming factors are applied, the scale of distances is altered and the law of red shifts is no longer linear. The rate of expansion increases more and more rapidly with distance. The significance of this result becomes clear when we reverse the picture. Light that reaches us to-day left the distant nebulae far back in the dim past—hundreds of millions of years ago. When we say that the rate of expansion increases with distance, we are saying that long ago the universe was expanding much faster than it is to-day, that, for the last several hundred million years at least, the rate of expansion has been slowing down. Therefore, the so-called "age of the universe," the time interval since the expansion began, is much shorter than the 1,800 million years suggested by a linear law of red shifts. If the measures are reliable, the interval would be less than 1,000 million years—a fraction of the age of the earth and comparable with the history of life on the earth. The nature of the expansion is permissible, and, in fact, specifies certain types of possible worlds. But the time scale is probably not acceptable. Either the measures are unreliable or red shifts do not represent expansion of the universe.

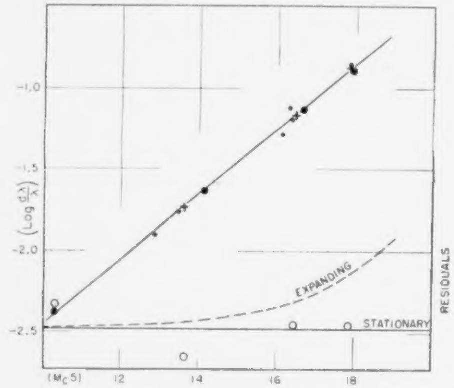


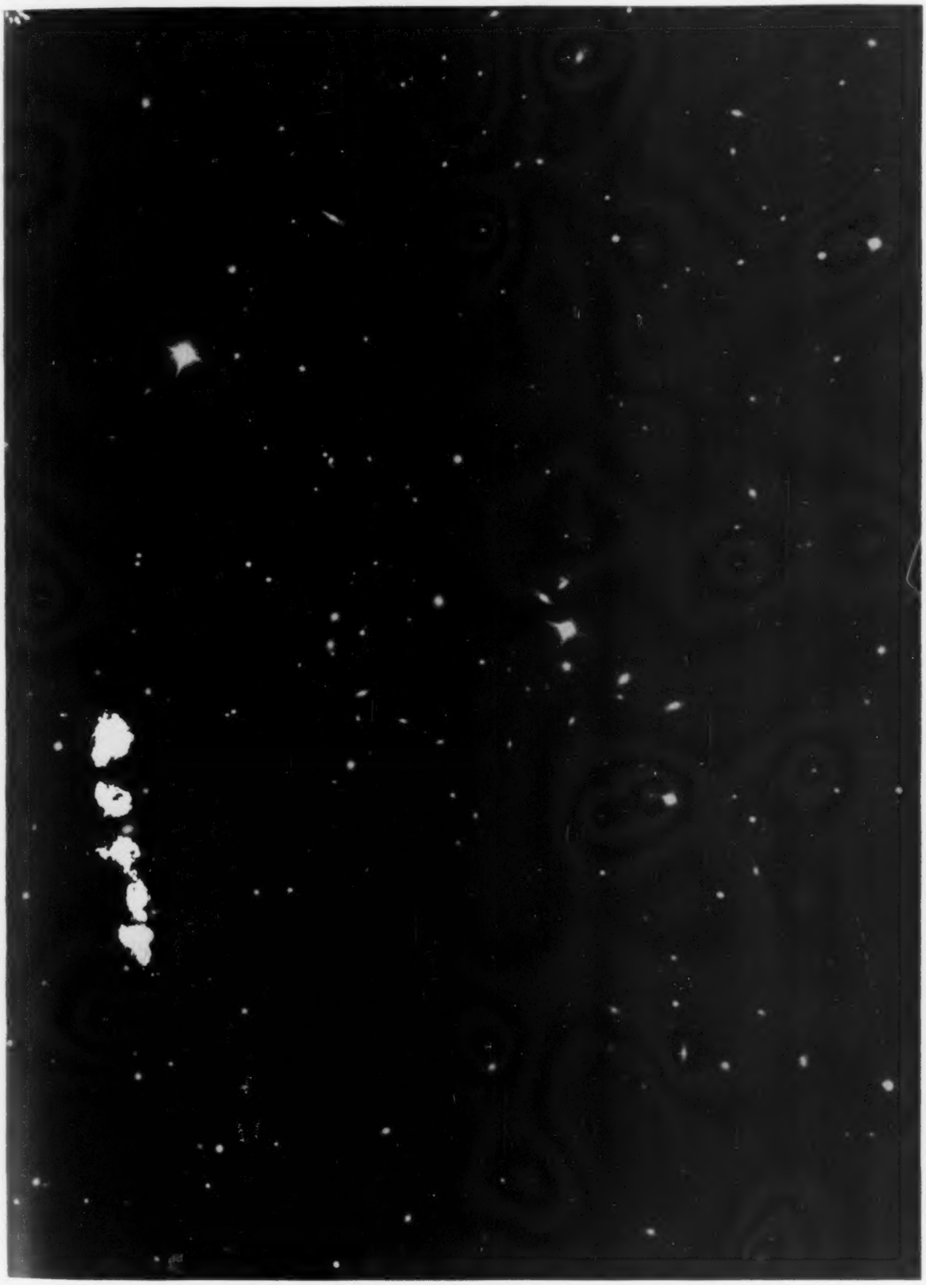
FIG. 1. THE LAW OF RED SHIFTS

The law of red shifts at very great distances is derived as a relation between apparent magnitudes of the fifth brightest members of clusters and the mean red shifts observed in the clusters. The relation, log $d\lambda/\lambda = 0.2\ m_5 +$ constant, shown as a full line in the diagram, indicates a linear law of red shifts ($d\lambda/\lambda =$ constant $\times$ distance). In the diagram, large discs represent clusters of high weight; dots, clusters of low weight; crosses, weighted means. Observed magnitudes have been corrected for all known effects (including the "energy effects," $3d\lambda/\lambda$), except recession factors. Thus, for a stationary universe, the law of red shifts is sensibly linear. For an expanding universe, the recession factors would be applied, and the law would depart from the linear form. Such departures, shown by the broken curve, imply that the rate of expansion has been slowing down, and that the "age of the universe," the time since the expansion started, is less than 1,000 million years. The diagram includes minor revisions of the observational data in accordance with recent investigations.

The Large-Scale Distribution of Nebulae

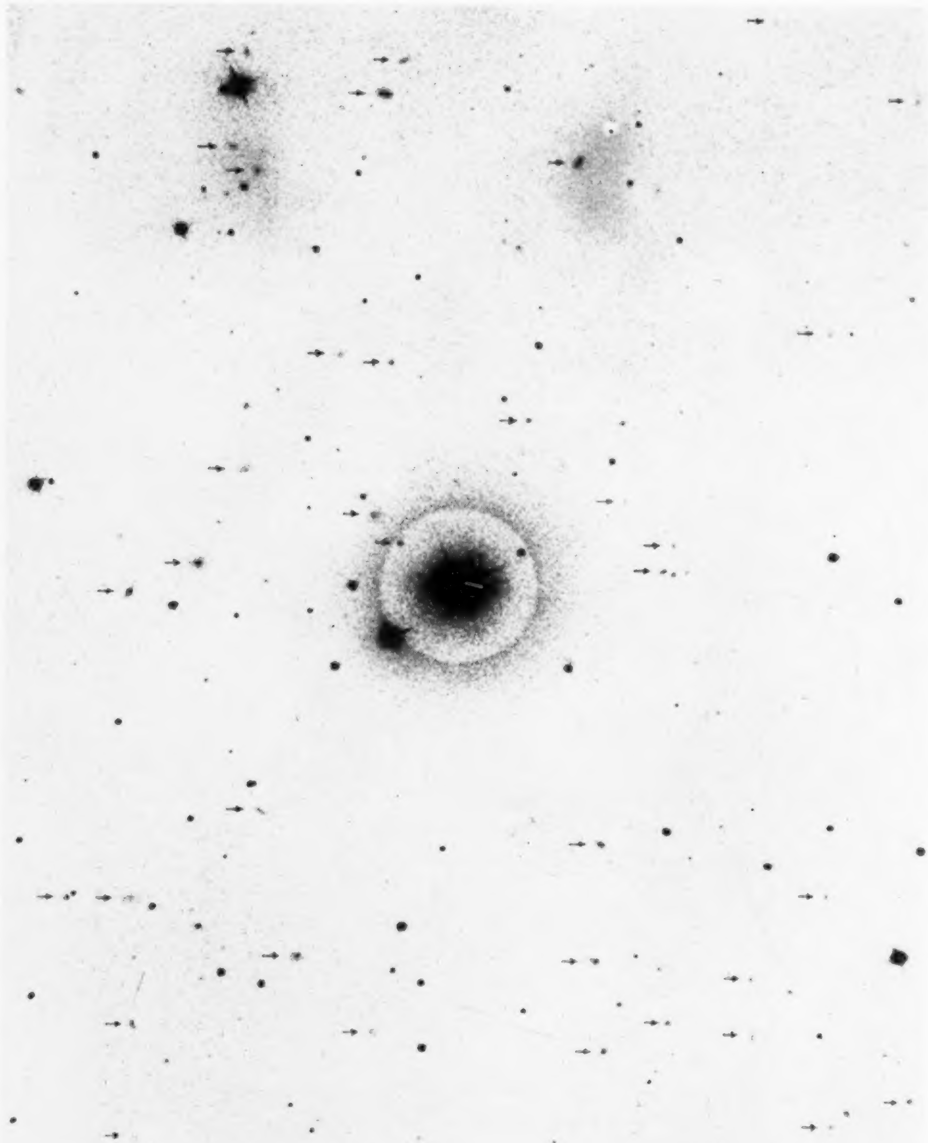
If the new formulation of the law of red shifts were unsupported by other evidence, the implications would probably be disregarded. But similar discrepancies are met in quite independent studies of large-scale distribution. Five sampling surveys (four at Mount Wilson and one at Mount Hamilton) made with large reflectors, furnish the numbers of nebulae per unit area on the sky to successive limits of apparent faintness. The results furnish the numbers of nebulae per unit volume in five spheres whose radii range from about 155 to 420 million light years on the stationary distance scale, or about 145 to 365 million light years for the expanding distance scale.

On the assumption that red shifts do not represent actual recession, the large-scale distribution is sensibly homogeneous—the average number of nebulae per unit volume of space is much the same for each of the spheres. Further confirmation is found in some of the recent Harvard counts of nebulae which fall within the area of the sky covered by the



THE CORONA BOREALIS CLUSTER OF NEBULAE

THE GREAT CLUSTER IN CORONA BOREALIS IS AT A DISTANCE OF THE ORDER OF 135 MILLION LIGHT YEARS. IT IS A COMPACT SWARM OF SEVERAL HUNDRED NEBULAE, MAINLY OF THE ELLIPTICAL TYPE. ON THE PHOTOGRAPH OF THE CENTRAL REGION (MADE WITH THE 100-INCH REFLECTOR), THE NEBULAE ARE MORE NUMEROUS THAN THE STARS.



A SAMPLE OF THE UNIVERSE

THE PHOTOGRAPH (A NEGATIVE PRINT, INSTEAD OF THE USUAL POSITIVE, TO SHOW VERY FAINT IMAGES) IS ENLARGED FROM THE CENTRAL REGION OF A SURVEY PLATE MADE WITH THE 100-INCH REFLECTOR, USING A LONG EXPOSURE AND A FAST EMULSION. SCATTERED AMONG THE FOREGROUND STARS (WHICH BELONG TO OUR OWN STELLAR SYSTEM) ARE FOUND THE FAINT IMAGES OF MANY NEBULAE DISTRIBUTED THROUGH A CONE OF SPACE, WITH APEX AT THE OBSERVER, REACHING OUT TO A DISTANCE OF THE ORDER OF 400 MILLION LIGHT YEARS. SOME OF THE BRIGHTER IMAGES (DARK IN THIS NEGATIVE PRINT) ARE MARKED BY ARROWS. THE STUDY OF SUCH SAMPLES IN SURVEYS REACHING TO DIFFERENT DEPTHS, INDICATES THAT THE LARGE-SCALE DISTRIBUTION OF NEBULAE IS APPROXIMATELY UNIFORM THROUGHOUT THE OBSERVABLE REGION OF THE UNIVERSE.

deep surveys and which are based on the same scale of apparent faintness. Sufficient data can be extracted from the reports to determine a mean density over large areas extending out to perhaps 100 million light years, and the result is in substantial agreement with those of the earlier investigations. All these data lead to the very simple conception of a sensibly infinite, homogeneous universe of which the observable region is an insignificant sample.

The inclusion of dimming corrections for recession, because they alter the scale of distance in a non-linear way, necessarily destroys the homogeneity. The number of nebulae per unit volume now appears to increase systematically with distance in all directions. The result violates the cosmological principle of no favored position, and, consequently, is referred to some neglected factor in the calculations. If the density appeared to diminish outward, we should at once suspect the presence of internebular obscuration, or, perhaps, the existence of a super-system of nebulae. But an apparently increasing density offers a much more serious problem. About the only known, permissible interpretation is found in positive spatial curvature, which, by a sort of optical foreshortening, would crowd the observed nebulae into apparently smaller and smaller volumes of space as the distance increased.

Spatial curvature is an expected feature of an expanding universe, and, together with the precise form of the law of red shifts, further specifies a particular type of possible world. Thus, if the measures were reliable, we might conclude that the initial cosmological problem had been solved—that now we knew the nature of the universe we inhabit. But the situation is not so simple. Just as the departures from linearity in the law of red shifts indicate a universe that is strangely young, so the apparent departures from homogeneity indicate a universe that is strangely small and dense.

The sign of the curvature required to restore homogeneity is positive, hence the universe is "closed"—it has a finite volume, although, of course, there are no boundaries. The amount of curvature indicates the volume of the universe

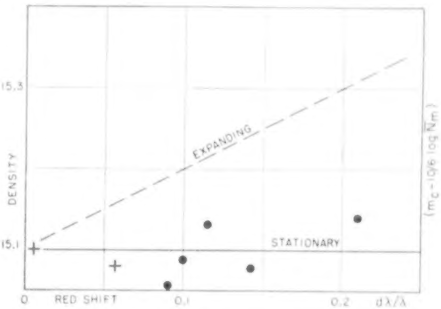


FIG. 2. LARGE-SCALE DISTRIBUTION OF NEBULAE

If N_m is the number of nebulae per square degree brighter than apparent magnitude m, then the average density (number of nebulae divided by volume of space), in arbitrary units, is represented by ($\log N_m - 0.6m$). Each point in the diagram represents a survey in which the observed *m* have been corrected for all known effects (including the "energy effects," $3\, d\lambda/\lambda$) but omitting the "recession factors," $d\lambda/\lambda$. The diagram indicates that, for a stationary universe, the density is independent of distance (or red shift). If the universe were expanding, "recession factors" should be applied, and the points would fall along the broken line, indicating that the density increases steadily with distance. In order to escape this conclusion, it is necessary to introduce still another effect, such as spatial curvature, which exactly compensates the recession factors. The dots represent surveys made at Mount Wilson and Mount Hamilton; the first cross, the Shapley-Ames survey to $m = 13\pm$; the second cross, Harvard counts to $m = 17.5$, extracted from *Proc. Nat. Acad.*, 24: 148, 1938, and 26: 166 and 554, 1940, and reduced according to the procedure used in reducing the deeper surveys.

—about four times the volume of the observable region. Such a universe would contain perhaps 400 million nebulae. The total mass, however, would be far greater than that which can be attributed to the nebulae alone.

Conclusion

Thus the use of dimming corrections leads to a particular kind of universe but one which most students are likely to reject as highly improbable. Furthermore, the strange features of this universe are merely the dimming corrections expressed in different terms. Omit the dimming factors, and the oddities vanish. We are left with the simple, even familiar concept of a sensibly infinite universe. All the difficulties are transferred to the interpretation of red shifts which can not then be the familiar velocity shifts.

Two further points may be mentioned. In the first place, the reference of red shifts to some hitherto unknown principle does not in any way destroy the validity of the theory of expanding universes. It merely removes the theory from immediate contact with observations. We may still suppose that the universe is either expanding or contracting but at a rate so slow that it can not now be disentangled from the gross effects of the superposed red shifts.

Secondly, the conclusions drawn from the empirical investigations involve the assumptions that the measures are reliable and the data are representative. These questions have been carefully re-examined during the past few years. Various minor revisions have been made but the end results remain substantially unchanged. By the usual criteria of probable errors, the data seem to be sufficiently consistent for their purpose. Nevertheless, the operations are delicate and the most significant data are found near the limits of the greatest telescopes. Under such conditions, it is always possible that the results may be affected by hidden systematic errors. Although no suggestion of such errors has been found, the possibility will persist until the investigations can be repeated with improved techniques and more powerful telescopes. Ultimately, the problem should be settled beyond question by the 200-inch reflector destined for Palomar. The range of that telescope, and the corresponding ranges of the dimming corrections, should be about twice those examined in the present investigations. Factors of 25 per cent. in the apparent brightness of nebulae at the limits of the spectrograph, and 40 to 50 per cent. at the limits of direct photography, should be unmistakable if they really exist.

Meanwhile, on the basis of the evidence now available, apparent discrepancies between theory and observation must be recognized. A choice is presented, as once before in the days of Copernicus, between a strangely small, finite universe and a sensibly infinite universe plus a new principle of nature.

SOIL AND WATER ECONOMY IN THE PUEBLO SOUTHWEST

I. FIELD STUDIES AT MESA VERDE AND NORTHERN ARIZONA

By Dr. GUY R. STEWART and Dr. MAURICE DONNELLY

SOIL CONSERVATION SERVICE, U. S. DEPARTMENT OF AGRICULTURE

CENTURIES before the permanent settlement of America by white men the Pueblo Indians of the arid Southwest developed methods of soil and water conservation which they used effectively to maintain production of their crops of corn and beans. The extent and variety of these early American methods of soil and water conservation are the subject of former articles in THE SCIENTIFIC MONTHLY[1] and elsewhere.[2]

Since then further work has been carried out to try to determine the effectiveness in soil and water conservation of the agricultural practices of the first cultivators at four centers of Pueblo settlement. The locations studied were the Mesa Verde Plateau, the primitive villages adjacent to Navajo Mountain in northern Arizona, the ruins found on the northern rim of the Grand Canyon and the early settlements of the San Francisco Mountains. The general situation of these places of study is shown on the accompanying map of the Pueblo Plateau (Fig. 1). In addition, further examination was made of the systems of flood water irrigation in use at the present day on the Zuni Reservation in central New Mexico.

MESA VERDE PLATEAU

Fig. 2 shows the location of the areas on Chapin Mesa, Wickiup Canyon and Wetherill Mesa, where further detailed studies were made on the Mesa Verde Plateau. The flood water ditch mapped previously was traced for approximately three fourths of a mile above Mummy Lake, showing that this drainage way would have intercepted an appreciable portion of the runoff from the upper part of Chapin Mesa. It is possible that a branch of the ditch may have extended to the east, which would have picked up an intermittent stream flow from the west branch of Soda Canyon. Nordenskiold[3] reported indications of such a

FIG. 1. MAP OF PUEBLO PLATEAU
PUEBLO CULTURE AREAS: I—RIO GRANDE; II—SAN JUAN; III—LITTLE COLORADO; IV—GILA; V—MIMBRES CHIHUAHUA. AFTER MAP BY SCHOOL OF AMERICAN RESEARCH.

[1] Guy R. Stewart, SCIENTIFIC MONTHLY, 51: 201–220 and 329–340, September and October, 1940.

[2] Guy R. Stewart, *Soil Conservation*, 5: 112–115, 1939.

[3] G. E. A. Nordenskiold, "The Cliff Dwellers of the Mesa Verde, Southwestern Colorado, Their Pottery and Implements."

supply feeder in his memoir describing conditions at Mesa Verde in 1889. John Wetherill,[4] in a discussion of evidences of early agriculture at Mesa Verde, has stated that he remembered seeing signs of such a ditch in his first visits to the plateau. This branch supply ditch could not be traced during the work in 1940.

Further soil profile studies along the flood-water ditch were made by H. K.

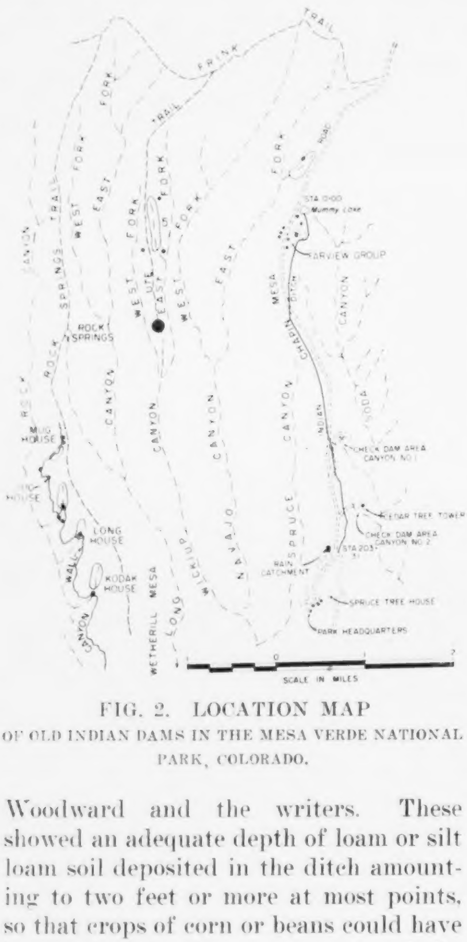


FIG. 2. LOCATION MAP OF OLD INDIAN DAMS IN THE MESA VERDE NATIONAL PARK, COLORADO.

Woodward and the writers. These showed an adequate depth of loam or silt loam soil deposited in the ditch amounting to two feet or more at most points, so that crops of corn or beans could have been raised in the greater part of the broad waterway itself in the same manner that the present-day Hopis and Zunis plant the flood-water stream beds. In addition, a gently sloping area of several acres, just below the Far View group of ruins, still showed evidence of field checks made with small boulders, indicating that the water running down to the ditch was intercepted in places to supply fields along the way. Where the flood ditch first crossed the modern highway, there is the beginning of a series of fields, with a gentle slope of $1\frac{1}{2}$ to 4 per cent., which have a relatively deep surface soil, thoroughly adequate for crop production if run-off were arrested and the rainfall supplemented by water from the uplands. The location of probable corn fields can be recognized at intervals, along the ditch, by noting the areas where water could be impounded with earth spreaders and simple field checks.

Local observers with whom the writers have discussed the value and importance of a supply ditch for flood water under the conditions found at Mesa Verde, have pointed out that the rainfall is probably only moderately higher in the uplands than it is along the lower part of Chapin Mesa. In answer to this it should be noted that the average rainfall of approximately 21 inches is well below the figure for rainfall in the corn-producing portions of the United States, amounting to about 35 inches for a sure crop. Though the strains of corn used by the Pueblo people were undoubtedly hardy and relatively drought-resistant, it appears likely that the 21-inch rainfall of Mesa Verde is lower than would be needed to produce maximum crops, even with specialized dry land types. With the lower rainfall of 7 to 8 inches occurring in much of the Hopi and Zuni country it is certain that appreciable amounts of supplementary moisture would be required. Even a slightly higher rainfall on the uplands at Mesa Verde would have supplied run-off which might have brought up the moisture on the lowland fields, when conducted there by the flood-water ditch, so that crop production would have been more cer-

[4] John Wetherill, personal communication, 1939.

MANCOS RIVER VALLEY IN COLORADO

THIS WAS THE ANCIENT THOROUGHFARE INTO THE MESA VERDE PLATEAU. VIEW UPSTREAM AT THE SOUTH END OF CHAPIN MESA.

GROUP OF WIDE CHECK DAMS NEAR LONG HOUSE, WETHERILL MESA

FURNISHING VILLAGE GARDEN PLOTS ON THE MESA VERDE PLATEAU.

tain. The assurance of a bumper crop, even on corn belt standards of water requirement, would be reached in most years at Mesa Verde if the run-off water from an area of surrounding land equal to one half the size of the corn field were brought onto the flood-water planting, provided all rainfall falling directly on the field itself was arrested and held in place for crop use. In a land where water economy is of paramount importance, any chance for an additional water supply would justify the labor and effort for supplementary supply feeders, such as the flood-water ditch.

would have formed only small cultivated areas about 10 feet by 12 feet in size. All the checks at the Wetherill Mesa sites were unusually wide, ranging from 30 feet to 50 feet across and apparently formed level plots 20 to 50 feet between the checks, before the centers were washed out. An accompanying photograph shows one of the longer checks laid down on a flat platform of rock, with a second check largely washed out and a series of further checks behind, which were still partly effective.

The major part of the Mesa Verde check dams were laid down directly on

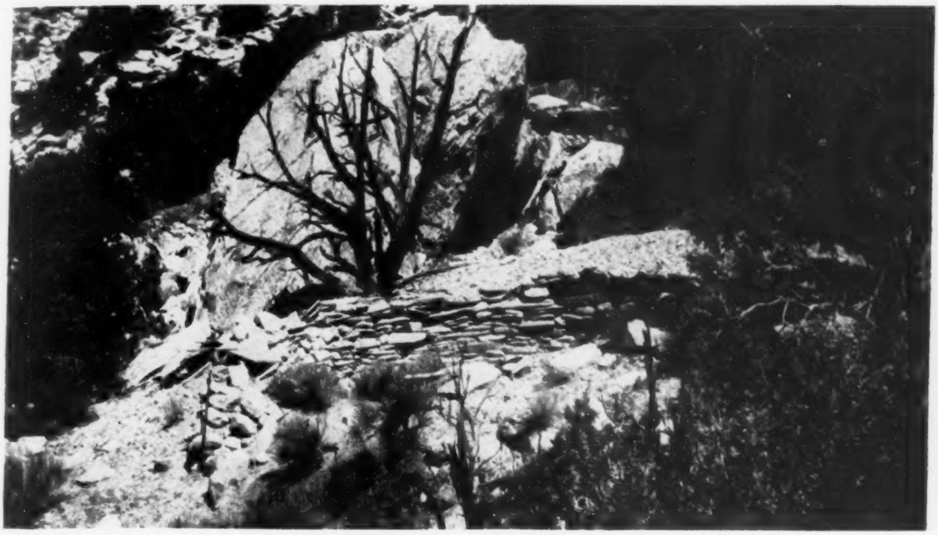
NAVAJO MOUNTAIN—A GREAT ROUNDED DOME OF SANDSTONE

Studies were next made of two small groups of check dams on the upper part of Chapin Mesa, where the checks were in most cases about 20 feet long, with one check of 45 feet. These checks are located on a canyon of moderate slope and originally would have furnished small, level garden plots which could have been used by occupants of the Far View group of dwellings.

Following this a series of check dam sites on Wickiup Canyon and at three locations on Wetherill Mesa near Kodak House, Long House and below Jug House were examined. The checks on the upper part of Wickiup Canyon would have formed long level plots, while those lower down, being on a steep slope,

solid sandstone. It is impossible to tell at this day whether the soil which was held by the checks was filled in by hand or whether the checks were built up by the gradual accumulation of soil suspended in flood run-off. Profile examinations showed that the checks contained originally about three feet of excellent surface soil. When abandonment took place and no repairs were made after freshet flows came down the water courses, it was inevitable that the centers of the dams would give way.

Preliminary examinations were next carried out of the evidences of primitive agriculture on Parke Mesa, which lies to the east beyond Spruce Canyon at Mesa Verde. Water detention checks were



WELL-PRESERVED CEREMONIAL KIVA
LOCATED ABOVE RAINBOW LODGE ON NAVAJO MOUNTAIN.

found around the principal ruins and a large group of check dam gardens were discovered on an east branch of Soda Canyon. In the fall of 1939, check dam areas had been found previously in tributaries of Little Moccasin Canyon.

A survey was made of the upper portions of Morefield, White and Waters Canyons, further east, without finding definite evidence of conservation works. Numerous ruins are located in all three sections visited, but the major part of these sites are dated by pottery shards as having been occupied in the period of

SMALL GARDEN PLOT
AT THE BASE OF NAVAJO MOUNTAIN, ABOVE RAINBOW LODGE.

BOULDER TERRACES ACROSS A FIELD
NEAR RED HOUSE RUIN, NAVAJO MOUNTAIN.

Pueblo II and earlier. The principal ruins on Parke Mesa, Chapin Mesa, Wickiup Canyon and Wetherill Mesa are believed to have been used through earlier periods into Pueblo III. This is the closing stage of the history of Pueblo life at Mesa Verde. The work of Douglass[5] and his associates had indicated that the final abandonment of Mesa Verde about 1300 A.D. came after a long drought. Should further work show that conservation structures are found associated largely with Pueblo III ruins on the plateau, it may indicate that the inhabitants turned to methods of soil and water saving late in the period of occupancy of this area. Was it a discovery brought in from elsewhere in the Southwest or did some inventive leader devise the check dams and flood water ditch system from observation of the flow of water and washing of soil on the local fields? The only hope of an answer will be to carry out further comparative studies of the types of check dam and ditch construction in other parts of the Pueblo country before an attempt is made to establish forms of related use and construction. Owing to the extent of the Mesa Verde Plateau there are still portions which should be visited and signs of agricultural use examined before tentative answers are proposed to these tantalizing questions.

[5] A. E. Douglass, *Nat. Geographic Mag.*, 6: 737–770, 1929.

Navajo Mountain Area

The country surrounding Navajo Mountain, which lies just above the extreme northern border of Arizona, was a notable center of early Pueblo life. The mountain itself is a great rounded dome of sandstone, the top of which is of Cretaceous and the slopes probably of Jurassic age. One of the larger sites lying near the southeastern side of the mountain is Red House Ruin, so called because it was constructed of red sandstone country rock. Two types of conservation structures were found adjacent to this ruin. The first of these were stream checks which were roughly made of local rock from the stream channels. Although the main part of these rocks are still in place, the garden plots were on a slight slope of $1\frac{1}{2}$ to 3 per cent. grade, and the surface soil has been almost com-

pletely removed, leaving an erosion pavement of variable sized rocky fragments.

A second type of water retention device was installed across the fields below and to the west of the ruin. This consisted of a type of simple boulder field terrace, designed to stabilize notably larger areas than the stream checks. These terraces were installed on slopes of 4 to 6 per cent. and produced a slightly sloping terraced area from which most of the soil has now departed. Gordon B. Page visited the ruin in a period of inclement weather and mapped some 23 field terraces adjacent to Red House Ruin. In addition, the writers found several groups of stream and field checks farther to the west. The first of these were stream checks installed in a small wash close to the ruin where the garden plots had lost all surface soil.

The next large wash to the west had been so heavily eroded by torrential runoff that stream checks were no longer recognizable. However, the four small draws beyond, continuing towards the west, were found to have groups of 10 to 12 checks in each in varying states of preservation. The original service of these conservation measures was the protection of an area that apparently included most of the village corn lands. The major part of the soils of the area appear to have been loose, open, sandy loams, which offered little resistance to erosion unless protected by vegetation. In recent times the entire site and its surroundings have been heavily grazed by bands of Navajo sheep so that grass and palatable herbage have been almost completely consumed, with resultant heavy washing of the surface soil after every rain.

At the base of Navajo Mountain, above Rainbow Lodge, several small garden plots were found near a well-preserved ceremonial kiva and primitive rock shelters. Here the garden plots were more nearly level and the surface soil had only been partly lost. An excellent instance of field scale checks was found across the land lying further down the mountain,

ROCK SHELTER, ABOVE RAINBOW LODGE, NAVAJO MOUNTAIN

approximately a half mile below Rainbow Lodge. Both stream and field checks were placed on land with about a 6 per cent. slope from which most of the surface soil has now been lost. Two field shelters, or food storage ruins, were found close to the former corn fields, testifying to the regular use made of these areas. Approximately two miles from these fields, along the canyon to the west, lies the Tohalena Gardens, formerly used by the Pueblos and now partly cultivated by present-day Navajos. This consists of a group of gardens, stabilized by boulder checks, where excellent surface soil remains. The land is watered by a permanent spring and is similar to the smaller groups of Hopi terrace gardens.

The time of occupancy of the Navajo Mountain ruins appears to have been largely during Pueblo III, tree-ring analysis having dated timbers from the Red House Ruin at A.D. 1143. Pottery shards were collected near Red House Ruin, as well as from the ruins adjacent to Rainbow Lodge and were likewise classified by Dr. H. S. Colton as being of the Pueblo III period.

Grand Canyon, North Rim

The North Rim of the Grand Canyon, especially on the Walhalla Plateau, was a thickly settled center of early Pueblo ruins of the small village type. Louis Schellbach, assistant park naturalist, aided the writers with information and also made Edward Hall's Archaeological Survey of the Walhalla area available to us.[6] The Walhalla Plateau consists of a rolling upland lying adjacent to the Grand Canyon gorge at elevations of 8,000 to 8,400 feet. The topography consists of a series of gently sloping ridges rising 200 to 400 feet above the intervening valleys. The tops of many of the ridges are broad and relatively flat so that slightly sloping land occurs along the crests of the hills. At the present time the uplands are covered with an open stand of ponderosa pine, which extends across part of the valleys, intermingled with groves of aspen. The early Pueblo settlements were nearly all located along the sides or crests of the hills so that the vilages would have com-

LOWER PART OF A GROUP OF STREAM CHECK DAM GARDENS
ON THE NORTH RIM OF THE GRAND CANYON.

[6] Edward Hall, "An Archaeological Survey of the Walhalla Glades, Grand Canyon, Arizona." Masters' Thesis, University of Arizona, Tucson, Arizona, 1938, Manuscript.

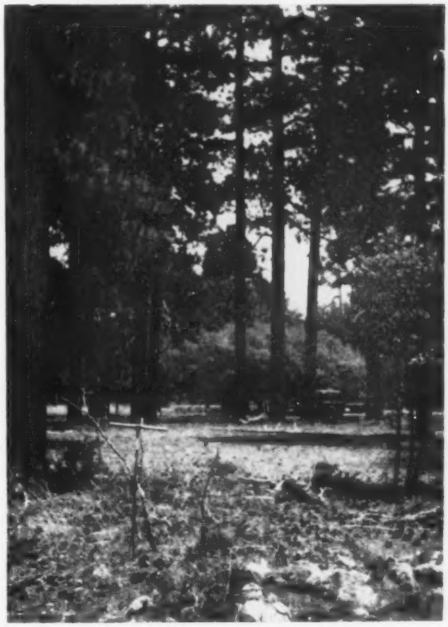
manded a view from one to another had the tree growth been thinner than at present, as was likely the case where agriculture was practiced actively.

A few boulder checks extending from 50 to 120 feet in length were found near many of the villages. Even three such checks would have helped to retain enough of the 27-inch rainfall, supplemented with run-off from adjacent land, for a village garden of ½ to 1 acre. Two long groups of stream check dams of 14 to 16 in number were found, one badly washed out and the other clearly recognizable, even though all surface soil had been lost from the slightly sloping checks laid down on a gradient of 8 to 10 per cent.

The largest agricultural site discovered in this section was on the side of a broad ridge of 8½ per cent. grade, near ruins 397 and 398 of Hall's survey, and covered an area of approximately 6 acres. The land was protected by long terraces of large, flat rocks at the bottom of the field extending some 800 feet in length. Further up the slope the material available was smaller and the boulder terraces were made up of a broad band of a number of rows of rock.

At the present day, with the moderate stand of Ponderosa pine there is a protective cover of about 2 inches of pine needles over most of the ground. This should give adequate protection against washing by rains. Profile studies showed the greater part of the surface soil had been removed with the formation of an erosion pavement. This suggests that there may have been a considerable period when the fields were exposed to surface washing after Pueblo occupation ended. Pottery shards examined by Dr. Colton appear to show the time of use of these sites extended from late Pueblo II, through Pueblo III.

The high elevation of the Walhalla Plateau, in excess of 8,000 feet, must have made it difficult to mature a corn



SWAMP POINT VILLAGE SITE
WITH A SMALL RUIN IN THE FOREGROUND.

PONDEROSA PINE
COMPLETELY FILLING A SMALL SHELTER AT THE SWAMP POINT VILLAGE SITE.

crop every season because of a relatively short frost-free period. Possibly the comparatively abundant rainfall may have compensated for this difficulty and continuous planting of early maturing ears of corn may possibly have developed a strain with a short growing period.

The winters on the North Rim are notably more severe than on the south side of the canyon, so it would not be surprising if the early residents had moved down into the canyon during the most rigorous weather of midwinter, though a shifting existence has not usually been associated with the settled Pueblo villages.

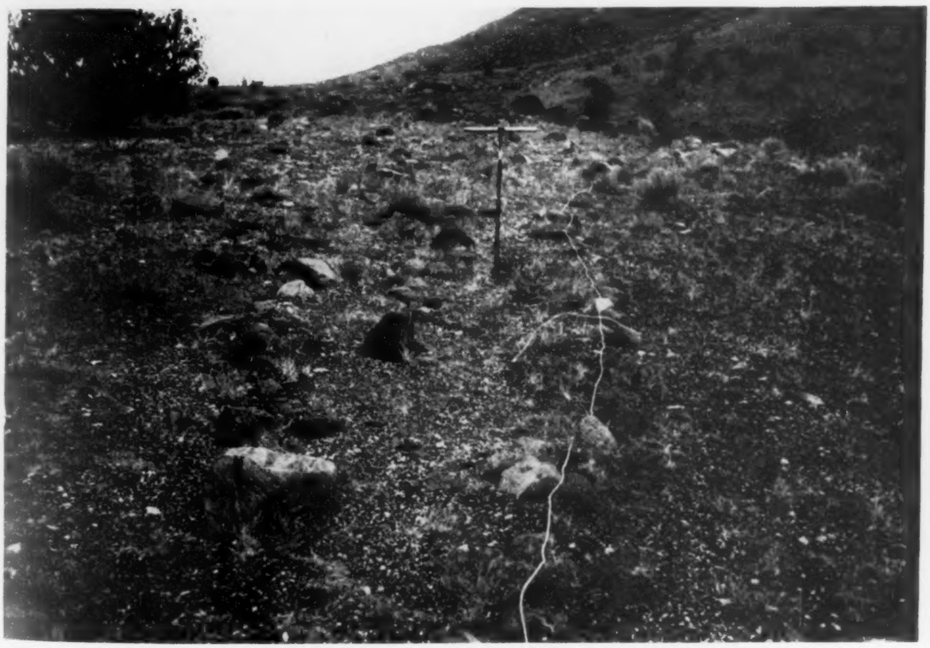
The portions of the Grand Canyon near at hand embrace some of the most striking scenery on the North Rim, ranging from Point Imperial up to Cape Royale with villages in sight of the great gorge nearly all the way. Probably the depth and steepness of the canyon were more valued for the protection afforded from enemies than for the scenic beauty which charms the modern visitor.

Most persons coming to the Grand Canyon at the present day have heard some reports of the vast size of the chasm extending 10 to 12 miles across, from the north to the south rim, and reaching down over a mile to the actual stream bed. The first white visitors who reached the canyon on the south side had no such background of information. In the fall of the year 1540 Garcia Lopez de Cardenas and 12 soldiers of Coronado's expedition made the trip of 120 miles from Awatobi in the Hopi villages, with a party of Indian guides. Students of Grand Canyon history believe the Spaniards and their Hopi companions reached a point along the south rim where the canyon is as deep as it is opposite the Walhalla Plateau. Castaneda[7] in his account of the Coronado expedition tells how Cardenas and his men came to the river, where they spent three days looking over the country and hunting for a passage down to the stream. None of the Spaniards at first believed the Indians when they told the Spaniards the size of the gorge or that the lower river bed was half a league wide. Finally

PRINCIPAL PORTION OF WUPATKI RUIN

[7] F. W. Hodge, "The Narrative of the Expedition of Coronado by Pedro de Castaneda." In "Spanish Explorers in the Southern United States, 1528–1543," pp. 275–387. New York, 1907.

HILLSIDE GARDEN PLOT
NEAR WUPATKI RUIN, LYING ON A FIVE PER CENT. SLOPE.



BOULDER CHECKS FOR WIND EROSION CONTROL
RUNNING DOWN THE SLOPE NEAR THE WUPATKI NATIONAL MONUMENT.

VIEW OF CITADEL RUIN, WUPATKI NATIONAL MONUMENT
SHOWING THREE ROUGH TERRACES BELOW THE RUIN.

three of the most active Spaniards climbed down about a third of the distance from the upper rim and then had difficulty in scaling the cliffs again. When they returned they informed Cardenas that the rocks down below them which looked quite small were in reality bigger than the great tower of Seville.

Further studies of ruins in the western part of the Walhalla Plateau showed that one ruin, Grand Canyon Number 383, located on the top of a relatively level ridge, was surrounded by some 24 garden plots scattered at random over the area adjacent to the ruin. These plots varied in size from 10 feet by 12 feet up to 75 feet by 15 feet. The material used to form the borders of these plots was relatively small rock, which was probably reinforced by brush and soil to retain the rainfall and impound any run-off which came down the gentle slope.

Preliminary examination of ruins near Swamp Point, towards the Powell Plateau, lying over 40 miles from the Walhalla sites, revealed a series of long boulder checks near a small village site and showed the wide distribution of conservation work on the North Rim.

San Francisco Mountain District

The country in the San Francisco Mountains, surrounding Sunset Crater and other recent cinder cones, was comparatively thinly settled with scattered small Pueblo communities prior to the cinder and ash eruptions which have been dated by Colton[8] as having occurred about 885 A.D. Surveys made by the Museum of Northern Arizona[9] showed a rapid increase in early settlement in the period from 900 to 1000 A.D., with the maximum number of primitive sites occupied in the period from 1100 to 1200 A.D. Colton has suggested that the presence of the volcanic ash was highly beneficial to the agricultural use of the land and made it possible to cultivate corn on many fields, formerly unproductive. The recent work of Duley[10] upon the infiltration of water into soils under vegetative mulches has shown that one great value of such mulches is that they pre-

[8] H. S. Colton, *Geo. Review*, 22: 582–590, 1932.

[9] Harold S. Colton, *Bull.* 104, pp. 1–68, 1932. Smithsonian Institution, Bureau of American Ethnology.

[10] F. L. Duley, *Proceedings*, Soil Science Society of America, pp. 60–64, 1939.

CHAVEZ PASS SITE

SHOWING LARGE TERRACE WITH PRIMITIVE RESERVOIR TO COLLECT SURFACE RUN-OFF.

vent puddling and sealing of the surface soil, a process which occurs when raindrops fall directly upon bare soil containing fine particles. Under a vegetative mulch the passage of water into the soil continues at a steady rate so that run-off and soil washing are both reduced. Infiltration effects similar to those obtained from vegetative mulches may be obtained from mineral mulches if they do not break down with raindrop impact into a fine suspension. Many kinds of volcanic ash are lacking in particles of colloidal size, hence a surficial deposit of such volcanic ash would insure good infiltration of precipitation. Colton's hypothesis receives support from this fact of the effect of volcanic ash on infiltration of precipitated moisture.

Preliminary studies of evidences of early agriculture in this section were made by the writers, especially around the ruins north of the San Francisco Peaks included in the Wupatki National Monument. Several groups of village garden plots are located adjacent to the principal ruins. Three of the best-formed terrace gardens are on the north side of the Citadel Ruin. The upper plot was 74 by 39 feet with about a 3½ per cent. slope, the middle 33 by 103 feet with a 5½ per cent. grade, and the lowest plot was 84 by 6 feet, lying approximately level. Dr. Colton informed one of us that profile excavations were made in these terraces at the time of the reconstruction of the Citadel Ruin and showed the sloping terraces were formed by filling in with village refuse. This could indicate these plots were highly productive garden areas when they were in use, though the upper surface soil has been removed by run-off since the period of occupation ended about 1200 A.D.

A set of very simple sloping terraces lie on the hillside to the southeast of the principal portion of Wupatki Ruin. Here a series of six plots with a slope of 3 to 4 per cent. have been made by digging into the hill behind, the size of the individual garden plots ranging from 18 feet by 19 feet up to 24 by 18 feet. At the present day a rocky erosion pavement covers the plots, through the washing away of surface soil on the exposed slope.

FIG. 3. CHAVEZ PASS SITE IN ARIZONA

An interesting group of fields were examined in company with David J. Jones, custodian of the Wupatki National Monument. These fields lie some 2 miles from the main Wupatki ruin. The area consists of a series of sloping tracts of land with a gradient of 5 to 6 per cent. towards the south and southwest. The entire site was covered with coarse black cinders of variable depth, in most places approximately over six inches of deposit. Several series of boulder checks were found on the exposed parts of the tract running up and down the slope, the checks being spaced approximately six feet apart. These checks would have given protection from the prevailing east and west winds and were probably reinforced with brush in the same manner that the Hopis reduce wind damage at the present day.

The Chavez Pass site is a large double ruin, lying some 50 miles southeast of Sunset Crater and was outside of the area of the cinder and ash eruptions that came from this cone. The inhabitants, however, are generally considered to have belonged to the same Pueblo culture group as those settling in the San Francisco Mountain district. The village was placed at the point of a steep hill with sloping land on three sides. Fig. 3 shows a sketch map of the site, as well as the probable agricultural use made of the adjacent land during the period of occupancy extending from Pueblo III into Pueblo IV.

The areas labeled "Terraces" were the plots adjacent to the ruins which would have made excellent gardens during the time the village was in use. All this land would receive some additional water from local run-off. The possible reservoir for collecting surface water is an interesting feature of this ruin and consisted of a circular excavation 150 feet in circumference and some 6 to 8 feet deep at the center. Colton[11] and others are of the opinion that the use of local water sources such as this may have been one of the principal reasons for the abandonment of many early Pueblo centers. The agricultural land in the terrace plots in most cases had a slope of $1\frac{1}{2}$ to 3 per cent. and the surface soil has suffered appreciable loss. The large terrace surrounding the reservoir is nearly level and more of the surface horizon has been retained than on the balance of the land.

(To be concluded)

[11] H. S. Colton, *Science*, 84: 2181, 337–343, 1936.

THE OLDER DRIFT OF WISCONSIN

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REACHING from the western border of Wisconsin in Pierce and St. Croix counties eastward to the neighborhood of Merrill, Wausau and Wisconsin Rapids is the region of Older Drift. The last—Wisconsin—glacial invasion did not reach it except to send fingers of outwash along some of the southward flowing streams. On the north, the region is bounded by the great Kettle Moraine of the Wisconsin glacier and its associated outwash. To the south and east is the Driftless Area. The boundary separating the Older Drift region from the Driftless Area is rather ill-defined due to the absence of any well-marked, continuous terminal moraine such as marks the terminus of the Wisconsin glacier. Hummocky recessional moraines are, however, not uncommon in the region of Older Drift. The topography of the region is varied, as is well illustrated by the soil map. The region includes parts of the Western Upland, the Central Plain and the Northern Highland. The characteristic rocks and preglacial topography of each area strongly affect the soils and surface features of the corresponding parts of the Older Drift region. The observations here recorded were made mostly on the Western Upland in Pierce and St. Croix counties.

THE LOESS

Where not removed or buried by stream action, a deposit of buff-colored loess covers a part of the older drift. It is thickest near the bluffs overlooking the Mississippi, where it may be fifteen or twenty feet in depth, gradually thinning out to the north and east. It covers the southern half of Pierce County and the western part of Pepin County. It sends a finger north along the west side of Dunn County just to the east of the limestone escarpment marking the border of the Western Upland. This fine-grained, even-textured material is generally supposed to have been wind-deposited. It is the same as the loess of the Driftless Area and was apparently laid down during the same period. Its source may have been the outwash along the Mississippi. At any rate, its presence suggests a time when wind work was very active. Since the loess overlies the older drift and is absent on the younger drift, it was probably deposited during the period of the Wisconsin invasion or the preceding Peorian interglacial period, possibly during both periods. It is interesting to speculate on the conditions prevailing over that portion of the area not covered with loess.

WIND-POLISHED BOULDERS

A partial answer to the question just suggested is found in the character of the glacial boulders. Those at the surface, in the region of Older Drift, show the unmistakable evidence of profound scouring by wind-driven sand and dust. Quartzites and resistant sandstones are polished and fluted (Fig. 1, *left*). Igneous rocks of uneven resistance are pitted. Amygdaloids are found with the harder nodules projecting and with trails of the softer rock extending to the leeward side, protected by the more resistant nodules. Even-textured rocks as basalts and some quartzites have the typical "Dreikanter" shape (Fig. 1, *middle* and *right*). Pebbles of this type are especially abundant and may be found by hundreds in an hour's time. If at the surface, even large boulders weighing a

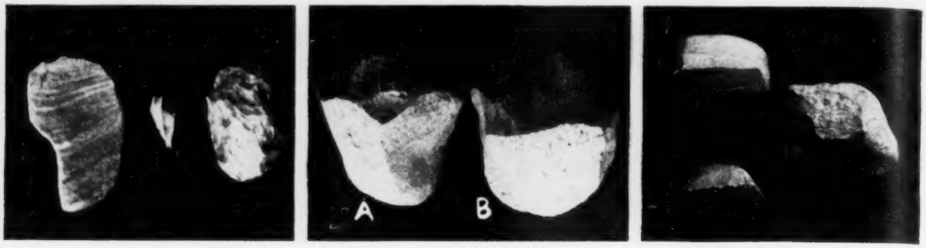


FIG. 1. WIND ETCHING
Left: ON PEBBLES OF SANDSTONE AND QUARTZITE. *Middle:* ON IGNEOUS ROCKS; (A) FINE-GRAINED GRANITE; (B) BASALT. *Right:* ON BASALT PEBBLES.

ton or more each often show a dreikanter shape. Perhaps half of the boulders in an average farm stone pile show evidence of wind abrasion.

None of these wind-etched pebbles and boulders were observed on the surface of the younger drift and only at or near the surface of the older drift. However, a number of large boulders which were uncovered in a gravel pit near St. Croix Falls, Wisconsin, were seen to be thoroughly etched. This is a region covered with Wisconsin drift. Surface pebbles in the same locality showed no signs of etching. This suggests that the etching was accomplished in this case before the final advance of the glacier which covered them with red outwash, the source of the gravel. Etching is little in evidence on the level lowlands of earlier outwash in Pierce and St. Croix counties since these are generally well covered by a dark prairie soil, possibly largely derived from the same wind-driven dust as the buff covered loess to the south. But wherever an outlier or a glacially deposited hummock projects above the later deposits, there the pebbles and boulders are consistently etched and polished. Etched pebbles are abundant also along the older terraces of the Kinnickinnic, Rush and Eau Galle rivers, streams which rise within the region of Older Drift. No field work was done along streams such as the Chippewa and the Black, the headwaters of which are in the younger drift to the north.

The question arises as to whether the drift beneath the loess also shows the effects of wind abrasion. Examination of the few available exposures along roads and gullies which are cut through the loess discloses a considerable number of pebbles which are apparently wind-polished, but the more conclusive dreikanter type, showing prolonged wind work, is not in evidence. Further search and more favorable exposures are needed before this point can be settled.

Agates

The Older Drift region in Wisconsin, although not covered by the Wisconsin glacier, was invaded at least twice and perhaps three times by earlier ice sheets. When geologists describe the deposits of the Wisconsin invasion they speak of the "Red" drift, deposited by ice crossing the iron measures and therefore containing much reddish material, and the "Gray" drift which came with the Keewatin ice and so missed the iron-bearing formations. The older drift is also red or gray and probably for similar reasons.

In the red drift of both the older and the younger ice sheets are great numbers of agates, generally known as "Lake Superior" agates. Locally, they are called "Carnelians," since most of them contain red chard or carnelian. Red gravels contain innumerable fragments of them. Occasionally they are found up to four or five inches in diameter. Some are of remarkable beauty and when free from cracks make excellent

material for the lapidary (Fig. 2, *top, left*). They are found in a great variety of patterns. Colors are mostly white, pink and red. Examination of many specimens can not but arouse curiosity as to their origin, a point upon which mineralogists seem unable to agree.[1] Most do agree that the agates were deposited in rock cavities. It is not clear, however, whether they came from silica gel (a colloidal solution) or from a pure solution in waters carrying alkali salts. Neither is it clear as to how the materials reached the cavities, whether through feeding tubes or, through pressure, between the microscopic crystals said to make up the chalcedony. Nearly all agree that they grew or developed from the outside toward the center.

Many of these agates contain geodes in the center with the quartz crystals pointing inward. Rarely the crystals are amethyst. Not uncommonly the nodule consists of alternate bands of chalcedony and crystal quartz. In this case often one can make out the layers of inward pointing crystals and the next inner layers of chalcedony laid down over the rough points of the crystals (Fig. 2, *top, right*). Additional layers of agate smooth out because the deposit is thicker in the depressions and thinner on the points. This indicates that the crystals were formed before the next inner band of agate and (perhaps) constitutes an argument against the current theory that the entire agate was formed from a mass of silica gel. It would seem that in order to lay down these alternate bands of agate and crystal quartz the solution must change, perhaps in the amount or nature of impurities present, perhaps from a pure to a colloidal solution and back again. Some specimens show a half dozen or more of these alternating lay-

[1] An excellent discussion may be found in chapters 10 and 11, "Quartz Family Minerals," by Dake, Fleener and Wilson.

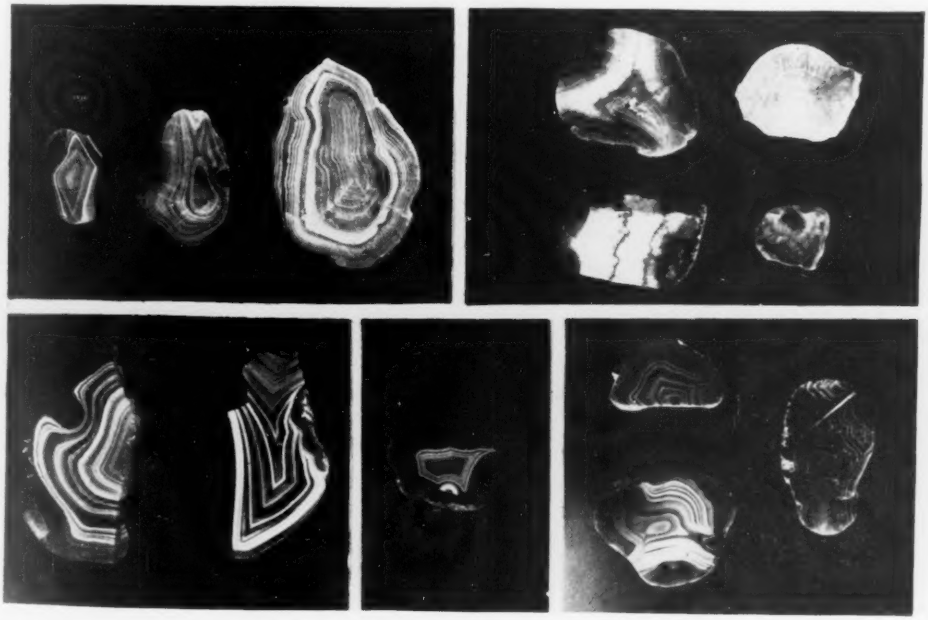


FIG. 2. EXAMPLES OF AGATES

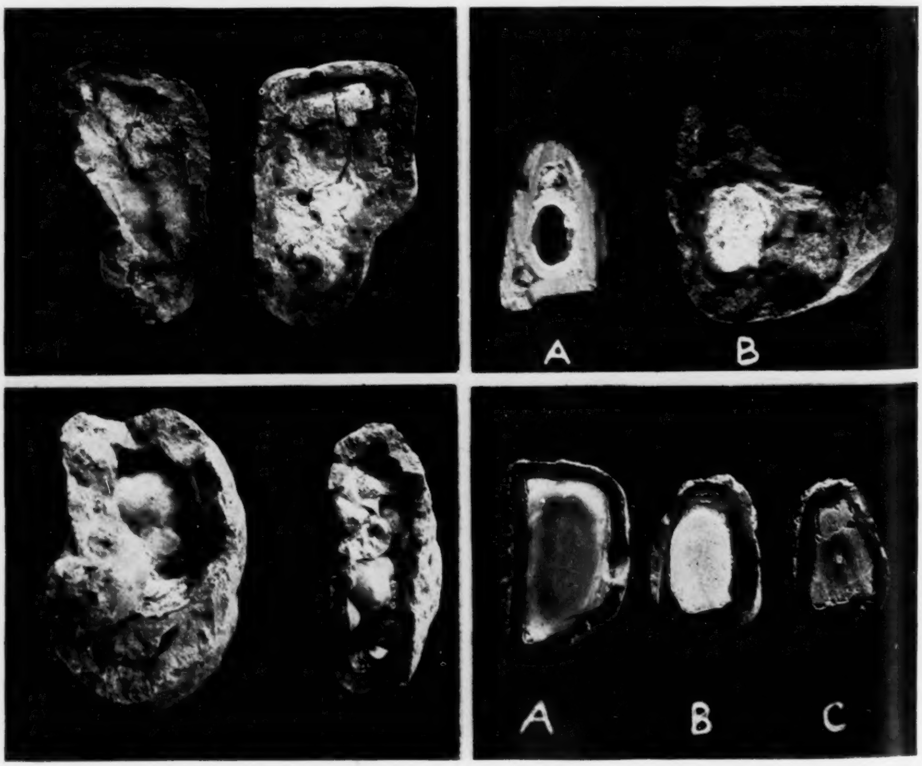
Top: left: TYPICAL LAKE SUPERIOR AGATES. *Right:* AGATES SHOWING ALTERNATING BANDS OF CHALCEDONY AND CRYSTAL QUARTZ. *Bottom: left:* AGATES SHOWING THICKENING OF THE LAYERS IN ANGLES. *Middle:* CROSS SECTION SHOWING "FISH EYE." *Right:* "TUBULAR" AGATES.

ers. It is also interesting to note that in the case of agates the cross-sections of which show sharp angles in the layers, "Fortification" agates, the layers are often much thicker in the angles, thus in some cases doing away with angles as the center is approached and adding a pleasing variety to the pattern of the polished specimen (Fig. 2, *bottom, left*).

Few of these agates show evidence of "feeding tubes" through which the solution may have entered the cavity. Occasionally one is found in which the tubes or something resembling tubes does exist and seems to have a distinct relation to the pattern of the bands (Fig. 2, *bottom right*). Such are known locally as "tubular" agates.

The most admired pattern is known as a "Fish Eye," a name which describes it adequately. Fish-eye agates if suitable for cutting are highly prized. The presence and position of fish eyes in an agate, unless already exposed, can only be guessed at. Once in a while, when agates are sawed, a lucky cut will show a cross-section of a fish eye (Fig. 2, *bottom middle*). It is then seen that they are not spheres, as one might suppose, but hemispheres. They apparently started as bubbles of silica gel adhering to the inner wall of the cavity. Subsequent layers of agate conform to their outlines.

In view of the peculiarities described above, it seems reasonable to suppose that these agates were not formed by the hardening and color segregation of a mass of silica gel but as layers by a varying solution. Whatever their origin,



IRON CONCRETIONS

Top: left: WITH CORE OF FINE SAND. *Right:* (A) CORE OF CLAY HAS SHRUNK, LEAVING CAVITY; (B) WITH CORE OF COARSE SAND. *Bottom: left:* SHOWING BOTRYOIDAL SHAPE OF SOME IRON CONCRETIONS. *Right:* (A) AND (B) WITH CORES OF SILTSTONE; (C) WITH CORE OF CLAY.

they are an interesting feature of the older drift terrain and give much pleasure to the many people who search for them.

Iron Concretions

Fragments of iron concretions are common in the older drift. In some gravel pits in the western part of the older drift sheets, iron concretions are so abundant, large and well preserved as to attract considerable attention. Strangely enough, they are apparently more numerous in the gray drift than in the red. They are mostly limonite, although bands of hematite are sometimes present. Typically, they appear to consist of shells of iron oxide containing cores of clay or sand. When dried, the material of the inner core may shrink, leaving a distinct hollow (Fig. 3, *top right*, A). Some are compound with several cavities in one specimen. When broken these give rise to fantastic names such as "Petrified Walnut" and even "Petrified Indian's Heart." A more puzzling type, sometimes quite large, has a core of rather hard siltstone (Fig. 3, *bottom right*, A and B). The core, whether of sand, clay or siltstone, is stained by iron oxide to a buff or, more rarely, a reddish color. It seems that the concretion grew in a bed of sand or of whatever material forms the core. The iron oxide was deposited among the particles of the original formation, cementing them together but not necessarily displacing them. Specimen B, Fig. 3, *top right*, has a core of coarse sand. The same kind of sand makes up a large percentage of the outer shell.

What strange whim of nature causes the iron oxide to prefer the periphery of the concretion to the core? The explanation may lie in the work of the iron-fixing bacteria. Various species of these bacteria have been studied and described. Their life processes involve the oxidation of soluble iron compounds to the insoluble oxide. It is possible to imagine a colony of iron-fixing bacteria gaining a foothold in a formation supplying the solutions necessary for their propagation. The colony grows larger and throws down the insoluble iron oxide. In time this iron oxide must impede the movement of ground water to the disadvantage of those bacteria near the center. Those on the outside thrive and build a shell of closely cemented material. Those on the inside die out as their supply of ground water diminishes. Theoretically, this process continues as long as the solution is favorable or until the whole formation is a mass of concretions. The latter theory may not be too far-fetched, since many iron ores are concretionary in structure.

The growth of the concretions under discussion was evidently interrupted while they were still separate. However, the fact that some of them are compound would indicate that several colonies of bacteria occasionally merged into one, resulting in several cavities in one specimen. The botryoidal appearance of many iron concretions also suggests the action of colonial bacteria (Fig. 3, *bottom left*). Similar shapes suggest the possibility of bacterial work in the formation of "Mammillary" iron ore and "Grape Ore."

The shape of sand and clay concretions suggests the possibility of bacterial action. Bacteriologists describe sulfur-fixing bacteria. They describe the action of bacteria in preserving humus and peat. They mention the possibility of bacterial influences in the evolution of petroleum. It may well be that bacteria play important parts in many other geological processes and that here is a rich field, almost unexplored, awaiting investigation by properly trained scientists.

MATHEMATICS AND THE MAXIMUM SCIENTIFIC EFFORT IN TOTAL WAR

By Dr. MARSTON MORSE

THE INSTITUTE FOR ADVANCED STUDY; PRESIDENT OF THE AMERICAN MATHEMATICAL SOCIETY

My subject is of concern not only to scientists but also to all those who are interested in a maximum effort to win the war. Every teacher and scientist is in fact, if not in law, a member of the great army fighting this war. Teachers of mathematics are primarily interested in the teaching of mathematics, but they are also interested in science as a whole, in particular in scientific research for military and industrial purposes and in education for the technical services of our army and navy. There is also the problem of the proper use of scientific men in time of war. Finally, they are concerned with the broad problem of education for freedom and democracy and believe that mathematics enters here again in a different but equally important role.

On March 3 of 1863, at the time of the Civil War, Abraham Lincoln approved an Act of Congress incorporating the National Academy of Sciences. Among the first members were the naturalist, Louis Agassiz, and the mathematician, Benjamin Peirce. High officers of the army and navy were included. In the words of the Act

> . . . the Academy shall, whenever called upon by any department of the Government, investigate, examine, experiment, and report upon any subject of science or art, the actual expense of such investigations, examinations, experiments, and reports to be paid from appropriations which may be made for the purpose, but the Academy shall receive no compensation whatever for any services to the Government of the United States.

Here was the first formal use of scientists by the United States Government.

In 1916 President Wilson established the National Research Council to facilitate communication between the government and the National Academy of Sciences. The council was still subject to the condition of receiving no pay. To carry on extensive investigations involving laboratory, traveling and secretarial expenses, and the expense of assembling groups of men in one place, these older organizations have required supplementation. In June of last year the Office of Scientific Research and Development was established by executive order. The chairman is Dr. Vannevar Bush. There are three subcommittees. Besides the older National Advisory Committee on Aeronautics, there is the National Research Defense Committee, with President Conant, of Harvard, as chairman, and the Committee on Medical Research, with Dr. Newton Richards as chairman.

The higher officers of these committees work without compensation from the government. The final research and technical development are carried on in the form of projects found in various universities and industries. Part of the expense, usually the salary, is borne by the university or industry, and another part of the expense, usually the overhead, is borne by the government. Some two or three thousand scientists are involved. That remarkable work is being done I have every reason to believe.

Mathematicians are being used in this research to a small extent but not to the extent to which engineers and physicists are used. This was inevitable at the beginning when the need was greatest for the rapid attainment of special objectives. It is clear that the machine nature of modern warfare places engineering

skill at a premium. But the war is much more than a war of machines, it is a war of invention, and of a new and more mathematical use of machines. In this connection I shall quote Dr. Jewett, president of the National Academy of Sciences and vice-president of the American Telephone and Telegraph Company. "Without insinuating anything as to guilt, the chemists declare that this is a physicist's war. With about equal justice one might say it is a mathematician's war."

It is clear that we require an all-out scientific effort. There are those who believe that we should have a military institute or institutes devoted to fundamental scientific research *without special objectives.* We already have at Aberdeen and Dahlgren and in the Office of Scientific Research and Development institutions working on special objectives. Those who advocate such new institutes feel that work done under pressure is not apt to be as profound as work more freely undertaken. The history of military invention shows how little one can predict the sources of inventions likely to be useful in war. My colleague, Edward Mead Earle, an authority on military history, writes as follows:

> Practically all basic inventions affecting naval, military, and aviation technology have been civilian in origin (as witness the rifle with interchangeable parts, the submarine, the machine gun, the tank, the airplane, poison gas, sound detection devices for submarines and airplanes, and most of the metallurgical discoveries which have affected armor and armor-piercing devices). The adaptation of many of these inventions to purely military purposes has, of course, been partly the work of civilians and partly the work of uniformed specialists.

In this connection I wish to describe an interesting example of a discovery by way of mathematical theory. An industrial firm was required to make a scientific instrument necessary for the prosecution of the war. Several models were known to the engineers in the blue-print stage, but it was not known whether any one of the models would be adequate or which one was the best. Considerable expense was incurred in building these models. The test was inconclusive. As a last resort a mathematician of note who was also an engineer was called in. In two weeks this mathematician had derived a mathematical theory of such models that said in effect, "Such and such models and only such models are possible, and type X is the best." This mathematical solution was complete and trivial in cost.

One can not generalize from one example, but it is becoming increasingly clear that an all-out effort will not draw the line too sharply between pure and applied mathematics. Oftentimes the difference between pure and applied mathematics is merely a matter of terminology. In papers in pure mathematics on the calculus of variations, for example, one can find principles, which appear in special cases in engineering books in the guise of the Ritz method or the method of the physicist, J. J. Thompson. Mathematical talent and engineering talent are neither interchangeable nor mutually inclusive. The only safe way in the present emergency is to use both to the maximum. In this direction lies the greatest strength, both actual and potential.

In Washington the Roster of Scientific and Specialized Personnel has registered tens of thousands of our scientists and technicians. Its officials are keenly aware of the importance of the proper use of scientific men. The Roster acts in an advisory capacity to the Selective Service Headquarters, reporting on shortages in various fields of intellectual work, and on the relative necessity of a man in his scientific occupation. It also makes recommendations to the Adjutant General's Office as to the use of young scientists whose induction has been ordered. To formulate policies on the

use of scientific and specialized personnel a national committee (under the chairmanship of Owen D. Young) is now at work.

I shall now turn to education and particularly to education in mathematics in its relation to the various training programs. We have available rather precise descriptions of the kind of training needed for college men who wish to enter the Signal or Air Corps of the Army or the Navy. Of these training programs that for the Signal Corps is perhaps the most technical. Officer material must have training practically equivalent to that of an electrical engineer. Needless to say, training in mathematics is fundamental and must include the calculus.

I have before me a pamphlet issued on March 1 of this year by the Navy and concerned with "Information for Institutions of Higher Education as to Class V-1 U. S. N." The introductory statement of objective is as follows:

> With a view to further expansion of procurement and training of prospective naval reserve officers, the Secretary of the Navy has approved the enlistment in the Naval Reserve of young men enrolled in accredited colleges, who, after enlistment in the Naval Reserve, may continue in college at their own expense, and in addition, be given naval training in an inactive naval status.

Under this program college freshmen or sophomores who meet the ordinary physical and educational requirements may enlist in the Naval Reserve and pursue the course V-1 for the first two years of their college course. I quote: "The pre-induction Naval training curricula will be prepared by the faculty of any accredited college which desires to participate in this plan and will conform to the normal program of that college provided it stresses physical training, mathematics and the physical sciences." The specific skills desired by the Navy are stated to be the following:

> (*a*) Skill in swift, accurate mathematical computation, and in the solution of problems of elementary algebra, plane geometry and plane trigonometry;
> (*b*) Skill in handling problems of general college physics; covering mechanics of solids, fluids and gases; light; and more fully heat, sound and electricity and their applications.
> (*c*) Good health and hard physical condition, the ability to swim, and the capacity for endurance of physical strain over extended periods. . . .

Students who satisfactorily complete the first two years' program may continue their college courses either in V-5 or V-7. In V-5, aviation cadet training is given and in V-7 the training is for midshipmen.

We turn now to the army aviation program with its proposed force of 2,000,000 men. Every bombing plane must contain at least one navigator. The problem of navigating a plane among the islands of the Pacific is very difficult. It is possible to lose as many men by faulty navigation as through enemy fire. It is clear that we must have tens of thousands of navigators. Are our students ready for this task? The answer is not one of credit to secondary school administration and policy. I am happy to say that the schools of New York, however, have performed their duty in a way that provokes admiration. But the same praise can not be given to all sections of the country. Fortunately, we have a disinterested appraisal of the situation from the pen of no less an authority than Admiral Nimitz, our Naval Commander in the Pacific. It is in the form of a letter written to an official of the University of Michigan. The letter of inquiry is written to Captain Lake of the Bureau of Navigation at the time when Admiral Nimitz was still the head of this Bureau. The letter follows:

> CAPTAIN F. U. LAKE
> HEAD OF THE TRAINING DIVISION,
> BUREAU OF NAVIGATION, WASHINGTON, D. C.
> MY DEAR CAPTAIN LAKE:
>
> When Admiral Nimitz visited the campus of the University of Michigan the other day, he

mentioned that there had been some difficulty in finding students in American colleges other than engineering who were sufficiently prepared in mathematics to make them available for training for commissions in the Navy. This situation ought to be called to the attention of educators in colleges and secondary schools throughout the country. I should deeply appreciate receiving a statement from you on this matter, especially if you could give me such facts and figures as would constitute a self-evident argument. I hope also that it will not be necessary to set any restrictions on the use of such information. It seems to me that educators should promptly recognize the danger, if there is any, from our past softening of our educational programs.

Very truly yours,
LOUIS I. BREDVOLD,
Member of the University Advisory Committee on Military Affairs.

The answer written by Admiral Nimitz follows:

MY DEAR PROFESSOR BREDVOLD:

Thank you for your letter of October 30. While we have not felt that it was our business to compile exhaustive data on our observations of the products of the educational systems of this country, we are in a position to give you some information on this subject.

A carefully prepared selective examination was given to 4,200 entering freshmen at 27 of the leading universities and colleges of the United States. Sixty-eight per cent. of the men taking this examination were unable to pass the arithmetical reasoning test. Sixty-two per cent. failed the whole test, which included also arithmetical combinations, vocabulary, and spatial relations. The majority of failures were not merely borderline, but were far below passing grade. Of the 4,200 entering freshmen who wished to enter the Naval Reserve Officers' Training Corps, only 10 per cent. had already taken elementary trigonometry in the high schools from which they had graduated. Only 23 per cent. of the 4,200 had taken more than one and a half years of mathematics in high school.

This same lack of fundamental education presented and continues to present a major obstacle in the selection and training of midshipmen for commissioning as ensigns, V–7. Of 8,000 applicants—all college graduates—some 3,000 had to be rejected because they had had no mathematics or insufficient mathematics at college nor had they ever taken plane trigonometry. Almost 40 per cent. of the college graduates applying for commissioning had not in the course of their education taken this essential mathematics course.

The experience which the Navy has had in attempting to teach navigation in the Naval Reserve Officers' Training Corps Units and in the Naval Reserve Midshipmen Training Program (V–7) indicates that 75 per cent. of the failures in the study of navigation must be attributed to the lack of adequate knowledge of mathematics. Since mathematics is also necessary in fire control and in many other vital branches of the naval officer's profession, it can readily be understood that a candidate for training for a commission in the Naval Reserve can not be regarded as good material unless he has taken sufficient mathematics.

The Navy depends for its efficiency upon trained men. The men are trained at schools conducted for this purpose and the admission of men to these schools is based upon the meeting of certain carefully established requirements. However, in order to enroll the necessary number of men in the training schools, it was found necessary at one of the training stations to lower the standards in 50 per cent. of the admissions. This necessity is attributed to a deficiency in the early educations of the men involved. The requirements had to be lowered in the field of arithmetical attainment. Relative to the results obtained in the General Classification Test, the lowest category of achievement was arithmetic.

A study has been made of the grades received in the examinations of candidates for enlistment in the Navy, classified geographically according to the location of the recruiting station through which the candidates applied for enlistment. It is to be noted that the proficiency in arithmetic in the eastern part of the country was strikingly greater than that of the middle west and west. The lowest average mark east of the Mississippi was equal to the highest average mark west of the Mississippi. The three highest average attainments in arithmetic were achieved by the recruiting stations in Troy, Brooklyn, and Buffalo—all in New York State.

May I express the hope that this information will be of assistance to you.

Sincerely yours,
C. W. NIMITZ, (Signed) F. U. LAKE,
Chief of Bureau By direction

The Bureau of Cooperation of the University of Michigan comments as follows:

When secondary schools eliminate not only trigonometry but also algebra and geometry from their programs, and then most of the reasoning problems of arithmetic, since pupils say they are too difficult, and offer as substi-

tutes general mathematics in the ninth grade, social mathematics in the tenth grade, and review of arithmetic in the eleventh or twelfth grade as the total mathematical program of the school, where along the educational ladder are pupils to obtain experience in reasoning and in practice in solving progressively more difficult mathematical problems? Where in the course of the four years are youth to find mathematical problems which will extend their intellectual horizons and stretch their mental muscles?

It is clearly not the fault of the teachers of mathematics that this situation has arisen except in so far as they have failed to convince school administrators and politicians of the importance of their subject. Where they have been allowed to teach mathematics in sufficient amount and where students have been encouraged to study mathematics the results in general have been reasonably successful. We are concerned here with a problem of public and community education to which I shall return later.

Our mathematical societies have been conscious of these problems for some time. One of the most effective of the subcommittees of the War Preparedness Committee of the American Mathematical Society and Mathematical Association of America is its Subcommittee on Education for Service. In the most recent *Bulletin* of the American Council on Education, No. 23, a statement is made that analyses should be made from the "training" and field "manuals" written by the armed forces to determine specific course content intended to provide background for later vocational training in the Army. Our subcommittee initiated such an analysis in so far as mathematics was concerned over two years ago and published its report over a year ago. This report has been sent to 5,000 secondary schools.

More recently, at the suggestion of officials of the Army Air Corps, on the nomination of the American Association for the Advancement of Science, a committee composed of the mathematicians Hart and Whyburn and the astronomer Wylie was appointed by the War Department with the following order:

To make a survey of the ground school courses offered in pilot and non-pilot courses in the Air Corps Flying Training System with a view to outlining preparatory courses to be offered in colleges and universities.

I quote from the committee's report to the War Preparedness Committee:

The committee carried out its investigations at various schools of the Air Corps in Alabama and Georgia during a ten-day period in January, and the confidential report of the committee was presented to the Chief of the Air Corps. In the report, recommendations were made concerning the content of a pre-training program for aviation cadets. These recommendations were accepted in full and are incorporated in the enclosed letter which has just been issued by Major General Yount, commanding officer of the Army Air Corps Flying Training Command. Copies of his letter will be sent to the presidents of all colleges in the United States and to various categories of administrators in the secondary schools.

It is logical and commendable that the Air Corps should request schools and colleges to emphasize the specified pre-training for aviation cadets, even though various cogent reasons make it appear unwise to *require* all cadets to obtain such training.

I shall quote one paragraph from General Yount's letter. It is entitled "Pre-training through Regular High School and College Courses":

If time limitations permit, it is recommended that a student get his pre-training through regular high-school and college courses, including the following: advanced high-school algebra; at least twenty-five lessons in solid geometry including the geometry of the sphere; plane and spherical trigonometry; descriptive astronomy; a college course in general physics; a course including a substantial amount of cartography. Additional courses in mathematics and the physical sciences would be useful for particular objectives within the Air Corps. It should be noticed that many of the courses in the preceding program can be taken in high school.

The letter continues with a detailed account of the number of hours recommended in mathematics, astronomy, maps, physics, etc.

Before I leave this subject of techni-

cal training, I shall add one word directed to the women. There is much that can be done to prepare women students to be useful. I do not have time to go into this, but I recommend that they write to the American Council on Education, 744 Jackson Place, Washington, D. C., for its February *Bulletin* No. 22, which gives a "Report of the Committee on Women in College and Defense."

Finally, I wish to comment briefly on the need for education for freedom and democracy, both now and after the war, and on the relation of mathematics to such education.

The attention which mathematics is now receiving and its great usefulness as a technical aid in war works both to its advantage and disadvantage. When the war is over and guns and bomb sights can be forgotten, what will happen to mathematics? Men will turn to social and humane studies and to the arts and philosophy. Unless mathematics is somehow associated with the humane studies and with philosophy, its greatest values will be obscured and forgotten. It will be back where it was before this war.

The answer is simple, but the implications of the answer as to courses of action are far from simple. Mathematicians must make it clear to their students that mathematics is an essential factor in cultural integration, that its history, together with that of science in general, is most relevant to the growth of freedom, that without an understanding of mathematics one can not really understand philosophy, that mathematics is an art as well as a science and that since the time of Plato mathematicians have valued it as such. They must not leave it exclusively to the humanists and philosophers to integrate the knowledge of the day and give it spiritual unity.

Recently I read a series of addresses on "Liberal Education and Democracy" appearing in the *Bulletin* of the Association of American Colleges.[1] The points of view presented by some of the speakers left me apprehensive. The speakers were not hostile to mathematics; mathematics was even emphasized, but frequently for erroneous or insufficient reasons. One of the contributors writes as follows:

> Each of the traditional liberal disciplines has an essential contribution to make to a liberal education—pure mathematics with its unparalleled precision; the natural sciences, with their amazing technique for objective thinking in the world of physical fact; the social studies for the understanding they give us of man in society; the arts and literatures for their beauty and their moral and religious insights; history and philosophy for their cultural integration.

I quote again "pure mathematics with its unparalleled precision." Yet who wants to be precise except on occasion? To give play to the imagination, to create and form ideas, to have a mastery of language and logic, to have that freedom that comes from recognition of dogma, and the open acceptance or rejection of an axiom at will, to recognize how much one does not know, or can not know; these things are all in mathematics. It is true that history and philosophy give us cultural integration, but only when the history includes the history of ideas, and when the philosophy comprehends the insights of mathematics. Mathematicians can not expect their colleagues, the humanists and philosophers, to be broader than they are willing to be. They must share the burden of cultural integration. More Whiteheads and Sartons are needed.

[1] *Bulletin of Association of American Colleges*, Vol. 27, p. 50.

THE CHEMISTRY OF TIME

By Dr. HUDSON HOAGLAND

PROFESSOR OF GENERAL PHYSIOLOGY, CLARK UNIVERSITY

I

Most of us have wished, at one time or another, that we could return to earth a generation, a century or a millennium after death to see what it is going to be like. Some of us may just want to know whom our grandchildren will marry, while others are curious about the future adventures of mankind.

Many years ago H. G. Wells wrote a delightful story called "The Time Machine," in which a man invented a device enabling him to travel into the past or into the future along the time dimension while remaining stationary in space. In his story Wells has his time traveler say, "There is no difference between time and any of the three dimensions of space, except that our consciousness moves along it." But, as sensible people, we usually dismiss as the purest fancy the thought that time is something to be tampered with. By its very nature it seems to be the most unyielding aspect of our environment. Events are said to be as sure as "death and taxes." There is an objective, inexorable character to the irreversible march of time. "Time," according to Sir James Jeans, "does not cease to unfold itself at a uniform and uncontrollable rate which is the same for each one of us." It is just this view of time with which I propose to disagree, despite that fact that it seems to be an intuitive aspect of experience. I shall try to show that time is not a mysterious river flowing relentlessly on to eternity, but rather a system of relations subject to some degree of control. We shall see that there is nothing about time itself that prevents our speeding it up and slowing it down. In fact, experiments have been done which actually involve the practical projection of living organisms forward into the future.

II

We all possess a private, internal appreciation of time. We can gauge within limits equal intervals of the experience we call duration. Even asleep, our time sense continues to function. It is possible for many persons to waken themselves at predesignated times to within a few minutes after a night's sleep. However, our private time is not precise enough to serve the needs of society, and so man has measured time in terms of sharable recurring happenings, such as seasonal changes, lunar cycles and, best of all, the earth's rotation on its axis which he has divided into units of equal length—hours, minutes and seconds. With such a time scale as a standard, he has constructed mechanical clocks, and learned to standardize his internal time sense with his widely accepted time conventions.

Our public time is thus determined by relations of changing physical objects. It is meaningless except in terms of these relations. If the universe were really to run down so that all motion, including molecular motion, were to stop, time, it appears by any meaningful definition, must also stop, outlandish as this view is.

Since clock time depends on relative motion, let us ask ourselves what is the source of motion determining our private or psychophysiological time? We judge time with our brain. To keep our brain cells functioning they must continually burn foodstuffs. This burning or oxidation is dependent upon motions of molecules, as are all chemical processes. A series of experiments has shown

that our judgment of time depends on the speed of these processes.

Most chemical processes are known to be roughly doubled or trebled in speed for a temperature rise of 10 degrees Centigrade (18° F).[1] If private, psychophysiological time is determined by chemical velocities, raising our internal body temperatures (as might occur in a fever) should speed the reactions, thus making more chemical change and hence more physiological time pass in a given interval of clock time than would normally be the case. If, let us say, two minutes of private, subjective time were thus to pass in one minute of clock time we would think that time was dragging; on looking at the clock it would be slower than we think it should be. Lowering the internal body temperature, on the other hand, should have an opposite effect, making clock time seem to pass faster, since the reduced biochemical changes would make less time seem to have passed and our public clock would, in contrast, appear to run faster. In a fever, *other things being equal,* we should come early for our appointments, and at subnormal temperatures we should come late.

I outlined these questions about time to myself on the first occasion in 1932, when my wife fell ill with influenza and developed a temperature one afternoon of nearly 104° F. She had asked me to do an errand at the drug store and, although I was gone for only twenty minutes, she insisted that I must have been away much longer. Since she is a patient lady, this immediately set me to thinking along the lines just indicated and then hurrying to find a stopwatch. I then asked my wife to count to sixty at a speed she believed to be one per second without telling her why. As a trained musician she has a good sense of short intervals. She repeated this count thirty or forty times in the course of her illness, her speed of counting was measured with the stopwatch, and her temperature was recorded each time. She unknowingly counted faster at higher than at lower temperatures. On the strength of this the experiment was repeated with several volunteer subjects given artificial fever by diathermy. I later discovered some data published earlier by a French worker, François, on the frequency of tapping a prescribed rhythm at different body temperatures. All these data, both those from Paris and from my own experiments, showed the same result as regards judgment of time. What is really significant, the data conformed exceedingly well to the mathematical relationship known as the Arrhenius equation, which describes the rates of chemical change with temperature. In fact, one of the specific chemical speed-temperature relationships, a constant in the equation that had been observed in several studies of the burning of foodstuffs by living cells, described the speed of counting. These results, published in 1933, were consistent with the view that our sense of duration, other things being equal, acts as if it were directly proportional to the speed of some internal chemical pacemaker.

At about the same time, and quite independently, Dr. Grabensburger in Austria showed that ants and bees taught to come for food at a particular time came earlier if the temperature in their experimental room was raised, and later if it was lower than that used for standard tests. This behavior is clearly quite in keeping with our findings in connection with the human time sense.

It is rather appalling to think of the kind of world we might live in if we did not possess a beautifully precise apparatus for keeping our internal body tem-

[1] On the Centigrade scale water boils at 100 degrees and freezes at zero degrees. This is in contrast to the Fahrenheit scale on which water boils at 212 degrees and freezes at +32 degrees. One degree Fahrenheit is 5/9 degrees Centigrade. Temperatures below the zero points on the respective scales are referred to as negative or minus temperatures.

perature constant. All animals, other than birds and mammals, lack this thermostat for regulating their internal temperatures. To such animals a linear time scale such as we have adopted as our public standard would be meaningless. For a difference of 30° Centigrade (54° F) between summer and winter, time must pass for the so-called "cold-blooded" animals[2]—frogs, reptiles, insects, etc.—roughly ten times as fast in winter as it does in summer. What kind of public time standard would we have devised if we lived in a world with a time warp of this order of magnitude? If an hour in a warm house corresponded to sixty subjective minutes, an hour out-of-doors on a winter's day would seem to us six minutes long! Public time-keeping without our physiological thermostats would indeed be a problem.

With our physiological thermostats permitting normal *internal* temperature fluctuations of less than a half-degree Fahrenheit around a mean of 98.6° F (37.0° C) the steady-state chemical events give us a linear, private time scale which we can standardize against our objective clocks. Biological oxidations, proceeding at a relatively constant speed, furnish us with a basis for our uniformly flowing time scale.

If our time sense depends primarily on biological oxidations we might expect that a variety of factors other than temperature would modify it. In recent years it has been shown by Sterzinger and Buehler that thyroid extract, known to speed biological oxidation, effects the time sense in the same general direction as raising the temperature, *i.e.*, public clock time appears to drag in contrast to our speeded "chemical clock." Quinine, which slows cellular oxidations, has the opposite effect. These relations had also been established earlier for the time sense in ants by Grabensburger. In acute emotional disturbances it is said that time seems to pass very slowly—the drowning man sees his life pass in review. Is this because of accelerated oxidations somewhere in the brain? In general, however, activity makes time appear to pass fast in contrast to the boredom of waiting and inactivity. Does this mean that there is a part of our brain concerned with the estimation of time that has its metabolism slowed during the general enhancement of activity by other parts of the brain? We simply do not know the answers to these questions as yet.

Our views about time are consistent with a number of older experiments. The concept of physiological time is by no means new. Aging is the result of a complex series of chemical changes. Jacques Loeb and others demonstrated long ago that fruit-flies and other so-called "cold-blooded" animals live longer the lower the temperature at which they are kept; du Noüy has demonstrated quantitatively that wounds heal progressively more slowly the older one is. For example, if a child of ten years heals over a wound of a given area in 20 days, a man of 20 will require 31 days to heal over a wound of the same area; a man of 30 will require 41 days, a man of 50 will require 78 days and a man of 60 will require 100 days.

It is common observation that time to the young passes much more slowly than it does in old age. A year to a man of 50 seems very short compared to a year at age 10. It has been established that metabolic processes in general become progressively slower with advancing years. This might make time seem to pass faster in old age, as indeed it does.

III

I wish now to suggest what may appear to be a bizarre proposition. It is that one can, for all practical purposes, construct a "time machine," making possible

[2] Such animals are, of course, not necessarily "cold-blooded." They are animals that do not regulate their internal body temperatures at a fixed level. Their blood is at the same temperature as their surroundings.

travel for living organisms forward into the future, although not backward into the past. This proposition is inherent in the essential nature of time, as outlined above.

One aspect of the relations between temperature and the speed of chemical reactions is that the curves describing these relations all take origin from the absolute zero of minus 273° C. At this temperature all molecular thermal motion ceases. The element helium, a light gas at ordinary temperatures, becomes a liquid at a temperature of minus 270° C (minus 518° F), and experimentally liquid helium has been cooled even a degree or so below its very low boiling point, but the absolute zero has as yet not been reached in the laboratory. Now, as we mentioned, the aging of living organisms is the direct result of a series of chemical changes. If organisms are exposed to lowered temperatures their aging is slowed. At the temperature of liquid helium, for example, rates of aging processes should be stopped or should proceed at an infinitesimally slow rate as compared to those at our body temperatures. If in some way it were possible greatly to lower the temperature of organisms so as not to produce irreversible and lethal changes and then later to raise the temperature again, the organisms would, for all practical purposes, be projected forward into the future during the time they were exposed to the very low temperature. Clock time for them would pass almost infinitely fast, while public time for the rest of us would proceed on at a constant rate. If such organisms possessed anything like memory resulting from the physico-chemical organization of their nervous systems, this, too, would be held in abeyance on cooling and started again on warming with no intermediate awareness of the lapse.

At this point you may be thinking that this is all rather amusing, but what of it? Living organisms in general readily freeze to death, and mammals like ourselves soon die if our internal body temperature falls even as little as 15°–20° F for a period of a few hours. But is it always necessary for cells to freeze when the temperature falls to very low values? Freezing is crystallization by definition. If heat is removed sufficiently fast from substances that normally freeze at definite temperatures they do not have time to crystallize, but instead pass directly into a different kind of solid condition known as the vitreous or glassy state. Such glassy or vitrified substances if slowly warmed will crystallize, *i.e.*, freeze. If they are very rapidly warmed through the temperature range in the vicinity of their normal freezing points they may pass directly from the vitreous to the liquid states. Pure water is hard to vitrify, since its speed of ice crystal formation is so very rapid. But watery solutions of substances composed of large molecules which are referred to as colloidal solutions are more readily vitrified. The large molecules of the substance in solution interfere with the ice formation. Thin films of gelatin solutions, for example, may be vitrified if plunged from room temperature into liquid air at minus 200° C. The films must be thin enough to permit a drop of temperature inside them of approximately 200 degrees per second, since otherwise the water will crystallize and not vitrify. We are indebted to Professor B. J. Luyet, of St. Louis University, for valuable contributions to this field of research and for applications of these ideas to the vitrification of living tissues which, after all, are complex colloidal solutions.

A number of workers, for one reason or another, have experimented with life at low temperatures. As early as 1893 R. Pictet showed that certain bacteria and protozoa could be revived after exposures to the low temperature of liquid

air. W. Stiles, in 1930, reasoned that rapid cooling might produce a reversible state of suspended animation by the avoidance of ice formation. Professor Luyet and others had made a number of interesting contributions, and late in 1940 Luyet and Gehenio published a book on the subject of "Life and Death at Low Temperatures." They presented experimental evidence indicating that below critical temperatures the vitreous state of certain colloidal solutions will remain indefinitely, there being no tendency to pass over into the crystalline state. These temperatures for colloidal solutions and for some protoplasmic systems, which are, of course, colloidal in nature, extend for only some 20 to 30 degrees below zero on the Centigrade scale (77° to 86° below zero Fahrenheit). The literature they cite shows that a great variety of organisms can survive very rapid cooling in the liquefied gases and subsequent rapid warming. Moreover, the length of time endured in the vitrified state, as we should expect, in most cases seems to have no effect on the percentage of organisms reviving. Upwards of 120 investigations have demonstrated vitrification and revival of many forms of plant cells, of many forms of bacteria, of a number of forms of protozoa and of certain small metazoans. Luyet and Hodapp were able to vitrify and revive the male reproductive sperm cells of frogs, and Dr. L. B. Shettles in 1940 has done the same thing for human sperm, obtaining a few per cent. revival after immersion in the liquefied gases.

The organisms withstanding this treatment must be small, since if they exceed more than a few hundredths of an inch in thickness they are likely to vitrify on the outside and freeze on the inside, thus producing death. Organisms with low water content also are, in general, more likely to survive the treatment than are those with a high water content. The main thing apparently that prevents the projection of a living contemporary human being into the future to accompany the "Time Capsule," buried at the site of the New York World's Fair, on its journey to 6940 A.D. is the fact that minus 270° C, the temperature of liquid helium, is not a great enough temperature drop from that of his body at 37° C to allow him to be vitrified throughout in less than one second, a condition necessary for tissue survival. This limited temperature range of 307° C (*i.e.*, from minus 270° to plus 37° C, the temperature of his body), his size and the high specific heat of water of which he is primarily composed, evidently precludes him from this interesting journey into the future along the time dimension. It would also be a prohibitively difficult task to keep him refrigerated for 5,000 years, although he would probably be safe in storage at 30° below zero Centigrade, since, according to Luyet, this is below the crystallization or freezing temperature of vitrified protoplasmic systems. Reviving him would conceivably be slightly less of a problem, since he could be dunked in a measured weight of warming liquid at high temperature and of known specific heat so that his temperature would rise rapidly as the bath's temperature falls and the two could be calculated to come to rapid equilibrium at 37° C, his normal body temperature. Such a hypothetical man should arrive with the Time Capsule at 6940 A.D. ready to interpret its contents to the "Futurians," no older than when he started his journey, since all his biochemical processes, including those involved in mental functions would have been fixed safely in the vitrified tissues.

While, for purely physical reasons, we clearly can not send a man on such a journey, we might just possibly be able to send his immediate son. During the past year Dr. Gregory Pincus and I have confirmed Shettles' finding that

human sperm can survive immersion in liquid nitrogen at minus 195° C (minus 383° F). Moreover, by technical improvements and pretreatments of the sperm we have increased the survival number from a few per cent. to 50 per cent., a concentration of sperm sufficient to insure easy fertilization of human ova. The revived sperm are just as vigorously motile as are those untreated and there is no reason to suppose that their fertilizing powers are impaired. Curiously enough, human sperm are much more resistant to this sort of treatment than are those of other mammals we have studied, which include rabbit, guinea pig, rat, mouse and bull. Luyet was unable to revive rat sperm after his successful experiments with those from frog. By special pretreatments we have been able to obtain from one half to one per cent. of live rabbit and bull sperm after immersion in liquid nitrogen. It is, of course, imperative now to get the revived sperm of experimental animals in appreciable yields so that we may test their fertilizing ability.

Vitrified sperm may deteriorate with time. We should not expect them to do so, but only further experiments can confirm our expectation that vitrified sperm will remain viable indefinitely. Shettles kept samples of human sperm at minus 79° C (minus 142° F, the temperature of "dry ice") up to 70 days. His data show a small decrease in the number surviving 70 days at this temperature compared to the number surviving a few minutes. But with his small yields and with the wide variability in samples showing these low yields of recoverable live sperm, we do not regard this apparent trend in a few experiments as especially significant.[3]

The problem of keeping sperm in suspended animation may be a very practical one for animal husbandry. The indefinite storage of the sperm of prize animals and their possible use to renew prize stock after it has degenerated by faulty breeding is at once apparent. A great horse like "Man O'War" could thus have immediate sons many generations after his death. It is even conceivable that at some time in the future we may systematically draw upon great geniuses of the past to father our human offspring. Possibly institutions which now store the memorabilia of our great departed may one day also store their vitrified sperm. Married couples today, when the husband is sterile, sometimes have children by sperm selected by their physician from a donor known to him but forever unknown to the couple. Social sanctions may ultimately extend this practice to illustrious men of the past not only for the fertile wives of sterile couples but for certain other women as well, especially since emotional revulsion might be reduced in the case of a non-contemporary donor long since dead. The historical test of genius would have operated so that part of each generation could be fathered by truly great sires.

While it still remains to be proved that vitrified sperm will keep indefinitely with fertilizing powers unimpaired, one is tempted with a variety of speculations. In a world rent by war and strife, the physically best are, in practice, selected for the most dangerous service. The possibility of the storage of vitrified and revivable human sperm available in the event of the donor's death may, at some future time, have considerable social significance.

[3] Since writing the above, Dr. Pincus and I have stored human sperm in dry ice, removing samples from time to time to test their motility. All samples thus tested over a span of 125 days have shown no decline during this time in the percentage of sperm revival compared to the percentage revivable immediately after vitrification.

WHAT ARE THE FITTEST?

II. WAR THROUGH THE GLASSES OF A BIOLOGIST

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The present application. In the first part of this article we have inquired into the origin of the concept of inevitable natural selection in an inescapable struggle for existence, a concept to which the term "survival of the fittest" was soon applied by a philosopher. We have tried to show how, in the minds of some philosophers, historians and international politicians, and doubtless in the minds of some biologists, the meaning of these words so shifted that the phrase came to signify a concept very different from the original. We saw that this interpretation of the survival of the fittest even became the foundation stone of national and international policies. The substituted concept of triumphant might was not new; the deadly national policies based upon it were not new; but the presumption that the policies had a sound and compelling biological basis, besides a historical basis, was relatively new—and it was also fallacious, as regards the alleged biological basis. This particular biological writer was even presumptuous enough to question the historical basis, which seemed to derive from the failure to look squarely at the whole picture. He made no claim to proficiency in the study of history; but, after all, history and sociology have their biological aspects and a biologist may be justified in remarking that it simply does not make sense to assume that social progress and empire-building have rested primarily upon an alleged "biological principle" that is too easily discredited. Narrowly selfish aggression, subjugation and mutual exploitation are not wanting from the pictures of past or present human lives; but if they, rather than the more obvious biological principles of cooperation and social interdependence, have indeed played the greater part in leading mankind at different times from savagery to high levels of culture with its idealism and respect for honorable and charitable human relations, then biology, the *science of life,* has nothing to offer to human *life*—and this is a contradiction in terms.

In the part that follows, I shall try to write as a biologist undertaking an objective view of his own species in the setting of the organic world, with full recognition of the inevitable limitations of view for one who has concentrated his attention upon certain parts and aspects of that world. It happens that uppermost in our minds at the present time is a military conflict of unprecedented scope and violence in which virtually the whole human race is directly or indirectly involved. In all the history, human or biological, of which we have any knowledge, there is no record of either an intra-specific or inter-specific battle for survival of comparably world-wide extent. In its scale, it is definitely something "new under the sun"!

If we take the present world-wide conflict as a social or biological problem and attempt to follow the solution along biological grounds, we start, as in the solution of all problems, with certain assumptions. Our first assumption is that the dominating strength of cooperative effort has been abundantly demonstrated in biology and history. We should like to take as our assumption of the second order that one side in this struggle, our

side, represents the spirit of cooperation and the other that of exploitation. With such assumptions of the second order offering a clear issue between sheer military power and the cooperative support of liberty and order, events up to the present time would seem clearly to favor the success of the former. We might be tempted to say the other side was right and we were wrong. Certainly we have had no choice but to accept the challenge of aggressive military power; we must seem to adopt the dogmas of military might; we must engage in a war of annihilation, it is only fair to say. Are we, then, to lose faith in our expressed ideal of cooperative orderliness in the light of the apparent evidence of its ineffectiveness and of our own now wholehearted and inescapable expression of the most violently aggressive spirit we can command?

The actual fact is that, regardless of *expressed* principles of action and ideals, the present issue can not be formulated as stated above. Those who proclaim the survival of the strongest actually assume, demand and receive the cooperation of enormous numbers of peoples of several nationalities; they have a highly developed social order. The cooperative spirit in the pursuit of a particular objective has perhaps never before been so fully and clearly exemplified as in Germany and Japan during the past decade or more. Their utter devotion to a common cause and their deadly earnestness in its furtherance can not fail to command our coldly intellectual approval. Of course, a defect in their exemplification of the ideal of social cooperation is that it stops at fixed national boundaries beyond which any cooperation must be one-sided and imposed upon others, beyond which the feature of mutuality is lost. Another possible defect in their exemplification of the cooperative spirit arises from its linkage with the conception that "might makes right." When outside enemies shall have been incapacitated for resistance, the winners may well lose the fruits of victory through unexpected application of their own theory within their own group. That would, however, be too late for our salvation.

What of the other side? Have those who have proclaimed most loudly the value of a better social order and of human cooperation, have they, ourselves and others, practiced any such mutual aid beyond their own national boundaries? There could be no question respecting our adherence to the ideals of cooperation, altruistic sympathy and mutual helpfulness, if lip service could be accepted as valid evidence. Would it not, however, be doing violence to the actualities if it should be said that during the past few years we have done anything in a practical and effective way to bring into the scope of our brotherhood of men the Chinese struggling valiantly for the right to live their own lives as adherents to the principles of peace and cooperation, the Poles, the Norwegians, the Czechs, the Belgians and a half dozen other peoples, to say nothing of the French, the British and our own good neighbors, the Canadians? Disregarding the trivial fringe who asked for peace at any price to ourselves, have we not generally demanded peace for ourselves at any price to every one else? Have we not as a nation been just as strict adherents to the faith in national interest and national superiority as have the Germans or the Japanese? These latter nations do at least include in their preaching, whether sincerely or not, the aim of promoting a more widely extended social order for the benefit of all, even if it does inevitably mean "we first." But we, too, know the slogan, "America first."

The avoidance of entangling alliances, doubtless an excellent doctrine in the time of its origination, has been one of our firmest articles of faith through all

the life of the republic. Self-sufficiency, self-interest and disregard of what might happen in the rest of the world and how it might affect us in the long run have been vital parts of our unwritten constitution, which has probably been preserved with greater integrity than has the written constitution. There may have been a few modifications represented, perhaps, by the Monroe Doctrine and the Spanish-American War; but, certainly during the past twenty-odd years, the isolationist and nationalistic policy has been more pronounced than ever before. As to the human race as a whole, our working principle of survival through cooperation has been as closely confined within our own boundaries as has that of any nation now our enemy. This is not a complaint but a bare statement of fact. To our credit let it be said that we have also kept our animosities within our national boundaries: we have not recently sought to conquer others.

But our blind concentration upon national interest, narrowly conceived, in contrast to world interest, or a broader conception of self-interest, is not the worst of it. What has been the internal situation? To what extent can we point with pride to any general willingness to sacrifice the interest of individuals and groups to a common interest? Again there has been lip service. No manufacturer would ask for a high protective tariff for his own personal enrichment, but rather for the benefit of American labor. Labor may have been a little more frank in demanding for themselves a higher share in the wealth produced by farming, mining and industry, but usually with no little emphasis upon the great benefit to the farmers and the miners of an increased purchasing power for industrial labor. Farmers have voted enthusiastically for subsidies and high farm prices. Some mining interests have worked for an artificial price for their product. I am not offering a word of criticism against any of these demands and efforts, nor expressing an opinion as to whether the several demands have been incumbent upon the respective groups *in the prevailing circumstances.* They are mentioned solely with the objective purpose of suggesting the desirability of a detached consideration of the question whether or not we have within our own boundaries manifested any high degree of internal adherence to the principle of mutual effort in the common interest. Personally I believe the answer is "No," but it is not necessary to argue the point. You may give any answer that seems justified by the facts; but it does seem clear that, if our present endangered situation has arisen in spite of substantial practical application of a national cooperative effort to serve best the good of all, the results up to now do not speak too well for the protective effectiveness of that spirit as it has been manifested during the past score of years. If we did not know before we ought to know now that it is hard to beat people who really work *together*—and really *work.*

We know of course very little in a direct way about internal cooperation in Germany and Japan, but we have a wealth of circumstantial evidence and, on the whole, it seems very clear that, if wholehearted cooperation and mutual aid within relatively narrow geographic boundaries can be the basis for survival, the Axis powers would have a very good case on their side. Most emphatically I do not assume that to be the case. Indeed the Axis powers have rendered a distinct philosophic service in reducing to an absurdity the idea that war is a means of effecting the survival of a superior kind of people. Who will be the victors—the supposed "survivors"? Whites? Yellows? Browns? They are on both sides, or may be. Teutons? Slavs? Mediterraneans? Caucasians?

Mongolians?, etc. There was never more scrambling of races in the armies of two sides in a war!

Obviously the conclusion is that, as a very large number of people have felt for a long time and perhaps many more in recent months, the world has so changed in respect to conditions of transportation and international communication that a nationalistic definition of cooperation and mutual aid is no longer sufficient, if indeed it ever was. Furthermore, the spread of education and communication and the wide extension of intra-group contacts and acquaintances, with development of group consciousness and recognition of group power, have resulted in a temporary state of increasing social disruption, not to say chaos, which is going to necessitate a much greater effort for consolidation than has yet appeared.

It should be obvious that cooperation and mutual effort toward a common end can be effectuated only under conditions of safety and order, and, as almost everywhere in the animal kingdom, safety and order can be attained only by the sacrifice of individual and small-group interests to those of a larger group. The real question confronting the human race at this time is—how broad shall be the group whose interest is to be paramount over the interest of individuals and of local or industrial groups? There is, I think, no difference in character in the answers given by different people and by different groups. The answer may be the industrial or the social class to which individuals pertain. The answer may be the State, that is to say, a particular State; the answer may be the aristocracy of birth or wealth; the answer may be the proletariat; the answer may be the hemisphere; the answer may be civilized man; or the answer may be mankind at large. The last answer seems to be that of Christianity, which has been widely extolled but never yet taken generally as politically practicable. Has it ever been the actual basis of national policy? The various "isms," so much to the front in recent years, seem *all* to have been satisfied with answers like the State or the Proletariat.

It may, then, be said that one answer to the question of why we face to-day such an overwhelming task is that we have not practiced in even half-way fashion, either among nations or within our own country, what we have preached with reference to mutual aid or social order, to say nothing of our past disregard of the frank scorn of our present enemies for our "naive" social philosophy and our deafness to their repeated bluff warnings. Neither radicals, liberals nor conservatives can put the full blame on others. What have been our national ideals? The so-called American standard of individual success through the mere attainment of wealth is now too generally discredited to justify consideration in this connection. What ideal has been most to the front but lives of ease for all, the chicken in every pot, two cars in every garage, a 40- or 30-hour week (for some, not for all), a soft life for every one, security without commensurate effort? We have sought a fool's paradise, than which there is nothing lovelier or more perilous. It is no disparagement of democratic ideals to admit that a people taught to believe that the State *must give them* security and comfort has some initial handicap in the acid test of conflict with peoples taught to believe that *they must give* security and power to the State.

Actuality of the struggle for existence. It is perhaps natural that biologists, impressed with the daily observation of "the struggle for existence" in the organic world, should be skeptical of the practicability of a general life of ease and security. Everywhere in nature we see such a struggle, and frequently on a

stupendous scale, as where millions are born for a pair that survive. We see everywhere in the animal and plant world the need for self-protection, for the maintenance of territorial areas and for resistance to external aggression. It is commonly accepted that "self-preservation is the first law of nature." We pass over for the present the fallacious politico-philosophical extension of this principle to justify aggression and subjugation. The extent of over-production, and that of the consequent culling, vary widely with different kinds of organisms. In one case, as just suggested, there may be millions produced for the tiniest fraction of one per cent. that survive. In another case a dozen or even less may be the measure of the biotic potential, with survival of eight to twenty per cent. I know of no case where a pair of organisms in nature normally give rise only to the number that survive, that is to say, of no species suffering no mortality from depredation, disease or starvation, exempt from necessary processes of elimination and free from interspecific competition for mere survival.

Parenthetically, it is true that, by some peoples, overcrowding has been advertised as an argument for wars for expansion of territory. It will be time to take seriously a complaint of overcrowding when those who broadcast to the outer world their pitiably congested conditions stop urging their own people to be more zealous and efficient in reproducing. It is not logically sound to promote a condition of overcrowding by producing greater crowds. Certainly it is not clear that the most populous countries are the most warlike, or that those who cry for expansion want space so much as power over others.

The mere preservation of life is not, however, the only feature of the struggle for existence. If I, as a biologist, can not envision a permanent state in which every able-bodied person loafs or plays most of the time when not asleep, the trouble may of course be in my capacity for social vision. There have been leisure classes and sometimes they have looked very nice. Perhaps at times most of us would like to belong to such a class. Has there ever been such a class that did not derive its living from the labors of others, and has there ever been any real service to mankind from the representatives of such classes, except as they have foregone leisure for genuinely hard work? Is anything worth doing easy to do? Was the shibboleth of "the strenuous life" a completely futile one? Is it not just possible that no one should loaf more than is actually necessary for the maintenance of physical and mental efficiency, except in so far as, for purely sentimental reasons, or for lack of assurance regarding the unforseeable potentialities of social contribution, we maintain the crippled and the aged? The immature need not be excepted, with the understanding that the "work" of children includes play and learning, which are necessary to the development of physical and mental efficiency and that it should also include a reasonable amount of useful social service as an essential part of the preparation for the physical, mental and moral responsibilities of complete citizenship. We are now told that we may have to live *hard* "for the *duration*." That may be for the duration of the war, or it may be for the duration of the order which may follow the war—for the duration of time. We are beginning to forget that we have heard that we need not sacrifice our standards of living for the national emergency; rather, we are beginning, and doubtless merely beginning, to face just this sacrifice.

In a very real way social science is a branch of biology, but biology is a very broad field and no one can encompass the whole area. Perhaps it would be

better if social theorists knew more biology and biologists knew more social science. A laboratory biologist may not answer but perhaps he is justified in asking the questions: To what extent generally can a high standard of living, in the sense of ease and security, be indefinitely maintained without the erection of tariff barriers and other economic and political walls around our own section of the earth's surface? and: How can we maintain such barriers and still be full participants in a world-wide social order ensuring security against the rhythmic recurrence of world wars? It is an unpopular question, and possibly a dangerous one even to state, but is the progress or the virility of the human race capable of promotion by any general guarantee of ease and security? Certainly no State boasting of the effectiveness of its particular "ism" has offered anything like general individual ease and security, to say nothing of freedom! "Youth demands security," we were hearing quite recently; the demand might be all right, if you can give satisfactory answers to the questions: Of whom? and For what end? At any rate youth have definitely not gotten security! We used to hear: "He that saveth his life shall lose it!"

Doubtless it will be deemed irrelevant to point out that the pioneers in America and those of the Great West found no softness or security except as they got it in the hard way. What people have continued to enjoy for long a period of easy life? There is no inconsistency between an ideal of mutual helpfulness and an ideal of hard work and self-reliance. What man needs in social help is not a guarantee of security through the accident of having been born in a particular community or group or through the purchase or gift of a membership ticket, but a chance to fight his own battle, not with the sword or gun if avoidable, but with his own physical, mental and moral powers exerted in his own and the general social interest.

Prognosis. We have implied that, in the present time at least, wars are social disorders, which, if unchecked by the most vigorous and concerted action of those who prefer peace to warfare under modern conditions, actually threaten the preservation of the race in any tolerable state of culture. Is there a conceivable remedy?[1]

We do not ask if the present war could have been prevented. I may think it could have been obviated had we done thus and so; you may hold that enduring peace could have been assured by actions of the very opposite nature. Let us steer away from the treacherous rocks of futile argument about the past and set our sails with all hands alert to weather the reefs that lie straight ahead. We are in a desperate struggle: either we shall lose and have no say about the future order; or we shall win and have a voice in shaping the future. I do not happen to have confidence in winning without sacrificing our recently cherished way of life. Be that as it may, and, at the best,

[1] The outlawing of war is the reverse of the philosophy of "pacifism" in the special sense. We may all be pacifists in the sense of having an abhorrence of war; but I could never see the position of the pacifist, who would enjoy the results of the protection of homeland and family by others but would not participate in the disagreeable efforts involved in protection; who would enjoy the order of a community without giving aid to the police or being ready to take his full part in an emergency. It is a fine line to draw between the "conscientious objector" and the parasite. We do not recognize the conscientious objector to tax-paying, although he asks much less of a sacrifice of his fellows.

It may be noted here also that some intellectuals seem to see only a fine line of distinction between defensive and offensive wars; notwithstanding that our whole system of internal order is conditioned upon the recognized capacities of jurymen of average intelligence to see the difference between killing in self-defense or in maintenance of order and killing for aggrandizement of individual or group.

I do not now see the chance for an "American-made" order after the war. It requires more national complacency than I can justify in the actual circumstances to imagine that we can subordinate the parts to be played in the final settlement by the Chinese, the British and the Russians. We do look forward confidently to having a voice in the afterorder, and, let us hope, an equal voice with those who were driven earlier to fight for some freedom to shape their own lives.

The question to which we address ourselves now is: Is warfare for survival, inescapable as it is to-day, to be looked upon as a forever-recurring phase of human history? We have already expressed our definite opinion that it is not a normal biological phenomenon, that it is not necessarily ingrained in man. Without going back over the previous discussion, let us deal now with the argument that inter-tribal and international wars have marked all human history. This does not make warfare normal in the sense of being inherent and inescapable any more than are murder and rape, any more than is infanticide or slavery. There was real philosophy in the comment of the old cannibal chieftain, who, having listened with wonder to the story of a veteran explorer about the thousands killed in a battle between civilized armies, inquired skeptically: "But how could you eat so many?" When told that the killed were not eaten, he exclaimed: "Don't eat them! Then, why do you kill them?"[2] Imagine the task of convincing the cannibal that an age-long practice was not ingrained, inevitable and entirely proper!

If one other story may be interposed, it is that of the shoemaker whose oracular utterances commanded the respect of his neighbors. They sought his opinion regarding the prospects for recovery of an aged friend who was critically ill. Upon due deliberation the shoemaker prognosticated confidently that the man would recover. When pressed for his reasons, he replied with solemn assurance: "Well, he always has!" Have we not all something of the shoemaker's faith in the past?

We outlive some of our practices or we do not. Warfare has become a practice so expensive and so destructive, not to life alone, for only ten or twenty per cent. are killed, but to any form of tolerable social order, that we may have to outlive it or else succumb to it. It may not do any longer merely to hope that we can somewhat prolong the intervals between wars—to strive, as a friend recently proposed, to put off the next war for thirty instead of twenty years.

I was reading recently a contemporary account of the black plague that swept across Europe in the fourteenth century. In the one city of Florence the number believed to have died was greater than the number previously supposed to have lived there. At least ten million, or about seventeen per cent. of the population of Europe, are supposed to have died (Pearl, 1939, p. 308). Everywhere there were demoralization and disruption of established modes of social life. Explanations of this continental catastrophe were not wanting. Wearied of the wickedness of his terrestrial subjects, the Almighty had sent this devastating visitation to wipe out the majority and make a fresh start; or it was attributable to the unfortunate operations of the heavenly bodies. One might have argued in vain that, although doubtless the plague was unavoidable as an initial localized outbreak, yet proper knowledge, determination and effort could have effected control—as we now know. Had we lived at that time, the plague would have seemed one of the inevitabilities. It had always been liable to occur. Who could govern the action of the Almighty or direct the movements of the stars? We could only have hoped that

[2] I wish I might credit this story to the real author, whose name I do not know.

it might be a long time before the next recurrence. There may be here a closer parallel than we are likely to imagine between the old fatalistic view of disease and the present concept of the inevitability of war. If only fifty odd years ago you had been with de Lesseps in Panama and had argued that malaria and yellow fever were not inherent in the situation and had prophesied that within twenty years the Canal Zone would be one of the healthiest places in the world, you would have been in danger of committal to an institution for the feeble-minded. Nevertheless, your prophecy would have been gloriously justified on schedule time. Science pointed the way, and Government took intelligent and effective action.

The future peace will, I feel sure, rest upon power and concert of power, without necessary equality of power, rather than upon adjustment and compromise. I am well aware that many social and political idealists will dissent when it is predicted that peace will not be based upon compact with the vanquished (it will not be if the other side wins!). It will not rest upon compromise or compact. It is a question of one's concept of the real nature of war. If one palliates offensive war one may expect a temporary peace. Undoubtedly there have been times in the past, when battles to the death between men and armies were looked upon as merely a particularly rough form of sport. It is not so now. Perhaps conditions have just changed; but the Germans and the Japanese sensed the change first. They have eliminated the aspect of sportsmanship; the principles, or "unprinciples," of gangsterism offer greater advantages. If offensive war is to be totally rejected as an instrument of national policy, if it is to be regarded as murder, arson and robbery on a grand scale, the perpetuators will not find themselves on an equal footing in the post-war order or deem it safe to plan for another. Take this opinion or leave it: if you know a better way to deal with national egotism in the nth degree, empowered with the scruples of gangsters, we should all listen, of course.

I do not yield to the defeatism that contemplates periodic wars because man is built that way. "There shall be no end to war in this world," we were told about 2,000 years ago; but we had always had plagues, and we do not now think of them as beyond control. We have heard that war is necessary to the virility of a people; but no evidence has been adduced to support an apparently specious contention: how can the race be improved by the elimination of the most virile? Wars are necessary to relieve overcrowding; but war is followed by an increase in birthrate, and not necessarily for the sturdiest. Wars are the inevitable results of economic strains; but what economic improvement can be effected by modern war? Wars are even less useful than the plague, but we do not palliate bubonic or yellow fever. To be sure, future wars will not be estopped by wishful thinking or talking; adequate organization supported by effective power is the desideratum. No doubt the power will have to be mundane in scope; the time for a pax Romana, a pax Britannica, a pax Americana or any other imperial pax, is probably gone. We may look forward to a "pax mundana."

May it be repeated that the war of to-day is biologically revolutionary? In its scope and its nature it is a phenomenon such as has never occurred before in all the history of animal life. A condition without precedent brings an aftermath without precedent.

But, interposes the skeptic, to have effective world organization you must first educate the people and that will take generations. Well, this war undoubtedly is going to be very educative,

on the "speed-up" plan, and widely so with respect to war as an intolerable calamity; but it is no discredit to democratic principles to point out that the control of yellow fever and bubonic plague did not have to wait upon general education and popular demand. Science showed how, and those vested with responsibility and power assumed control, having the sense and courage to adopt vigorous quarantine, eradication and other measures—and the people did not disapprove, although they had not had prior education or even any slight knowledge of the causes and conditions of the disease. For the control of war, as of pestilence, it will be necessary to educate administrative officers and representatives; then, of course, the farther the education of the people can be carried the better.

We have to deal realistically with war and the beginners of war. Whether or not all criminological theorists will agree, I believe it would be the general view that, if murder were rampant in the community, the murderers should be executed or confined. We are now confronted with war and the makers of wars, and the only proper action, whether one likes it or not, is to go just as far in annihilation, or in imposition of "durance vile," as is necessary to create a greater impotence for warfare and a greater distaste for war than some nations have thus far had. You *can* indict a people—*if* you can bomb them, and do not care to do it periodically.

I am optimistic, but certainly not overly assured, as to the development of an organization and a will to permanent world peace. It is conceivable that there will be a peace of adjustment and the initiation of another period of preparation for aggressive war. In such a contingency, we may well be distrustful of the preservation of any respectable social order. My hope for a solution of the crucial problem is based primarily upon the apparent necessity for a solution. Before the present crisis has past, unless I misjudge the prospect, the mother of invention will arise before us, as "a Phantom—with distrustful aspect, Terrible in beauty, age and power," and she will be pregnant with the machinery of enduring peace. We do not know what the baby will look like, but we may have to take and support her whether we had planned for her or not.

THE RURAL SCHOOLS IN WARTIME

Rural America has a tremendous responsibility in wartime. It must supply nearly half of the fighting men. It is providing nearly half of the workers in war industries. It must produce food for victory. It must hold fast to its democratic institutions and to the democratic way of living. In 1940 there were one million more young people under 16 years of age in rural than in urban America.

Only highly trained armed forces can win in modern warfare. Only skilled workers can produce war materials and food for victory. And only a people who have learned to understand and love democracy can defend it. Manpower and materials are necessary but unless we protect our democratic institutions we lose the very ideals for which we are fighting. Education is an integral part of the war effort, and without the public schools we can not have this education. It is significant that Great Britain has increased appropriations for public education each year since the war began. In the dark days ahead, rural America must devote all its natural resources and all its human energies to achieving victory and winning the peace which will follow. But it can not do this if it closes its schools. They are the foundation of democracy in both war and peace. It is essential to winning the war itself and to the preservation of democracy for which we are fighting that schools be kept open and the children provided with the facilities essential to this end.—*C. S. Marsh, in "The Report of a Conference on the Rural Child in the War Emergency."*

A STATE ACADEMY CHARTS ITS COURSE

By Dr. GEORGE W. JEFFERS

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THE revival of science in the sixteenth century revolved around such towering university professors as Vesalius and Galileo. However, while the universities seemed to be fit soil for the germination of the new science they were apparently unsuited for its rapid progress. Instead of centers of the new advances in science, they remained "seats of unproductive conservatism, mechanically repeating the formulae inherited from the Middle Ages."[1] During the seventeenth and eighteenth centuries the real pioneer scientists were without university affiliation for the most part. Descartes, Leibniz, Harvey and Leeuwenhoek were all private scholars. These men and others of their kind needed and sought intellectual companionship often found in small friendly groups. Thus it was that scientific societies, or "academies," emerged to furnish the bond between men of learning that the universities did not provide. Patterned upon the Academy instituted by Plato in 387 B.C., these new academies appeared first in Italy but soon spread over Europe and thence to America.

The distinction of being the first such academy of science probably belongs to the Academie Secretorium Naturae, which was founded in Naples in 1560. It was more than a hundred years before the Royal Society of London received its charter in 1662, although a group of kindred minds had been meeting regularly in that city for some time previously. It had existed experimentally and proved its use before being officially recognized. In France, the Académie Royale des Sciences was founded in 1666, and the Prussian Akademie der Wissenschaften in 1700. In this country the American Philosophical Society was first proposed by the many-sided Franklin in a printed circular letter distributed to friends throughout the colonies in 1743.

Franklin envisioned something broader than a merely local club; he had in mind a sort of intercolonial Junto. In his "Proposals" for the society, Franklin stated that now that the first drudgery of settling the colonies was over, there was opportunity for speculation and examination of the natural world. The period of "settling the colonies" was followed by the turbulent times of the Revolutionary War, and it was toward the end of the eighteenth century before other "academies" appeared. The oldest of our state academies of science would seem to be the Maryland Academy, growing as it did out of the old "Academic Society," which was organized in 1797. Of the city academies the records state that the New York Academy dates from 1817.

When we consider the difficulties of communication and transportation, it was natural that city academies should have gotten an earlier start than state academies. The formation of additional city academies of science seems to have definitely ended. None the less, the city academy has had a long and honorable history, and most of them are in a thriving condition to-day. The New York Academy, the St. Louis Academy, the New Orleans Academy, the Washington Academy, the Rochester Academy, the

[1] Eric Nordanskiöld, "The History of Biology," p. 142, New York: Tudor Publishing Company, 1935.

Boston Society of Natural History and others have had a long and successful existence.

Of the state academies, only seven were founded during the nineteenth century and all these, except the Maryland Academy, after the Civil War; three, in fact, during the closing decade of the century. With the opening of the present century the movement spread rapidly. If the present rate of organization is maintained we may expect soon to have an academy of science in each state except possibly certain New England states. These states have lagged in development of academies, for which there are doubtless good reasons which we shall not attempt to list here.

One might well inquire: Whence the momentum for the rapid spread of the academy movement in our own times? Certainly it can not be attributed to the conservatism of our institutions of higher learning. Our colleges and universities are no longer inhospitable to science, although in certain regions and in certain types of institutions the status of science is not all that could be desired. That the original *raison d'être* in some instances has been to provide a bond of fellowship is not to be overlooked, even if only one academy (Virginia) states as one of its objectives "to provide opportunity for . . . fellowship among its members." One contributing factor has undoubtedly been the paternal and fostering attitude of the American Association for the Advancement of Science. The association has helped to organize some academies. It has aided and strengthened the research programs of its affiliated academies. In its academy conference the association furnishes a forum where representatives of the various academies meet on an equal footing for the consideration of mutual problems.

Probably the academy movement stems from the positive desire to make science function in the lives of the citizens of the state by providing a medium through which the state may take advantage of the findings of science, thus helping both the academy and the state to contribute to the general good. This is borne out by the rather striking similarity of objectives of the various academies. For example, it is likely that most would approve the following statement of the Kentucky Academy: "To encourage scientific research, to promote the diffusion of useful scientific knowledge and to unify the scientific interests of the state."

Between objective and accomplishment there is often a great gulf. While this is probably as it should be, objectives are not to be lost sight of altogether. True, many academies can point with justifiable pride to specific attainments of con-

Organization and Membership of State Academies Affiliated with the American Association for the Advancement of Science

	Date of organization	Membership in 1940 or 1941
Amer. Inst. of City of N. Y.	1828	358
Maryland	1797	38
New Orleans	1852	270
St. Louis	1856	415
Kansas	1868	654
Wisconsin	1870	348
Indiana	1885	897
Iowa	1886	681
Ohio	1891	678
Nebraska	1891	184
Michigan	1894	1129
Illinois	1908	1151
Oklahoma	1909	475
Tennessee	1912	459
Kentucky	1914	345
New Hampshire	1919	208
North Carolina	1902	365
Georgia	1922	124
Virginia	1923	912
Northwest	1923	423
South Carolina	1924	281
West Virginia	1924	313
Pennsylvania	1924	445
Louisiana	1927	273
Colorado-Wyoming	1927	336
Minnesota	1932*	642
Missouri	1934	720
Florida	1936	346
Alabama	1924	360
British Columbia	1909	104
Mississippi	1931	140
North Dakota	1908	115
Texas	1892†	651

* Reorganized. Data on organization were gathered by Dr. W. H. Schoewe, of the Kansas Academy. Membership data from *Science*, 93: 2414, April 4, 1941. More recent data have been supplied for part of the academies.

† Reorganized, 1928.

siderable merit such as their publications, their summer field stations and their junior academy and science club work. Nevertheless, some academies would have difficulty in justifying their existence in so far as advancing scientific interests and thought within their communities is concerned.

Every one will agree that the aim of a state academy of science should emphasize service to science, not only to its own members but to the science of the state as a whole. While the first function of an academy should be the promotion of research, it is of equal importance to make known its work to the citizens of the state. The academy should likewise act as a clearing house for all the scientific activities of the state. Further, the ideal academy should be on intimate terms with the state's industry and commerce, especially with the greatest business within the state, namely, the state government itself.

Such objectives can not hope of full attainment so long as academies work chiefly upon the basis of one-year plans. Strictly speaking, the annual meeting should recognize such purposes. However, the business meeting is generally swamped by other matters of immediate but not of greater importance. The average academy meets once a year for a day or two, the usual run-o'-mine papers are presented, committees are appointed or continued, the retiring president makes an address and a good time is had by all. Only six academies—Indiana, Oklahoma, Texas, Tennessee, Minnesota and Florida—hold as many as two meetings a year. Contrast this with the situation in city academies: The New York Academy holds twenty-eight meetings, the St. Louis Academy fifteen and the New Orleans Academy five. Interestingly enough, state academy meetings are well attended and membership is on the increase.[2]

In the state academy we have a medium already at hand through which science can flow directly into the lives of our people. The academy can initiate and carry through projects that a national science organization can not undertake. The national organization can coordinate the work of various local groups and can inform one group of what the others are doing. But only the academy can do the job. Men and women are already susceptible to the magic of science, as witness the radio barker invoking the name of science to help him sell his wares. The American people have at their command the benefits and the gadgets of science, but this public remains woefully untouched by science as a way of life. This was made abundantly clear by the venerable A. J. Carlson in his Sigma Xi address in Philadelphia a year ago. Moreover, at no other period in our history have scientists been under such a peculiar obligation to consider science in the broader aspects of its effects upon human beings. Too long has the emphasis of science been upon material things.

I am well aware that it is not customary to report upon an experiment before it has even gotten well under way. But the experiment in socio-scientific planning recently inaugurated by the Virginia Academy of Science is so novel that I venture to describe it in the hope that its very audacity may stimulate other academies to project their thinking into the future along similar lines. Not that the Virginia plan will necessarily fit any other situation, but it should be of assistance to other academies in formulating plans of their own. I am persuaded that even if the Virginia experiment is not carried through to its logical conclusion, the results to date have justi-

[2] From 1936 to 1940 only seven state academies showed a decrease in membership, whereas twenty-two showed increases, and in five cases the change could not be computed. The largest decrease was 16.9 per cent., but nine had increases above this figure. *Science*, 93: 2414, April 4, 1941.

fied its beginning. The members of the academy have a new *esprit de corps* and an awareness of the obligations of science to the people of the state.

Through its twenty years of life the Virginia Academy has followed the pattern of most state academies of science: It boasts a membership of nine hundred; it has fostered research, especially among its younger members; it has organized and is now sponsoring a Junior Academy of Science; and it has a struggling but vigorous *Journal of Science.* If its material success has been more than that of some sister academies, it has been due largely to the good fortune of having had an unusually efficient and devoted secretary during its whole existence.

During the year that Dean Wortley F. Rudd was president-elect of the Virginia Academy he must have given more than the customary amount of thought to academy problems because, when he took office as president in May, 1941, he demonstrated that he knew where he was going. He immediately asked for authorization to appoint a committee on long-range planning for the academy. But before appointing this committee President Rudd consulted each member of the academy with regard to two questions that had been uppermost in his mind during the preceding year. These questions were:

1. What, in your judgment, should be the primary objectives of a state academy of science?

2. Please outline rather carefully, and in order of their importance, three or more distinct contributions that the academy may and should make to Virginia in the next five years.

The same two questions were sent to the members of the National Association of Science Writers, to the secretaries of all state academies and to a large group of distinguished scientists throughout the country. Returns from all these sources were excellent and the replies often make interesting reading. From the membership there were one hundred and fifty-two letters of response containing four hundred and fifty-seven suggestions. All these data were abstracted and the suggestions classified[3] under the following headings: Research; Publicity of Academy's Work; Science Education; Problems concerning the State; Science Clubs and Junior Academy; Guidance Program; Academy Meetings; Providing Science Materials; Water Pollution; National Defense; Science Museum; Problems concerning Industry; Retaining Virginia's Trained Scientists, and Miscellaneous. Since the items are here arranged in the order of their frequency, one can see that our scientists still conceive of the promotion of research as the primary function of a state academy of science. Research was mentioned in 71 per cent. of the replies, Publicity of the Academy's Work in 46 per cent., Teaching and Science Education in 44 per cent., and Problems concerning the State in 28 per cent.

The selection of the personnel of the Long Range Planning Committee was carefully arranged as follows: About twenty of the "most experienced and devoted members" were asked to nominate five or six persons who would meet the requirements for membership on such a committee. Nominations were not confined to academy members. From the resulting eligible list of around one hundred names, the final selection of nearly twenty-five was made by a small group around the president. Interestingly enough, not one person declined to serve.

Armed with the information from the questionnaire, President Rudd convened the Long Range Planning Committee on October 25, 1940. The response was in-

[3] By Mr. H. J. Davis, of Williamsburg, Va., through whose efforts the Virginia Junior Academy of Science was organized. Summaries of his report on data are available. Write Dr. E. C. L. Miller, Secretary-treasurer of the Academy, Medical College of Virginia, Richmond.

deed gratifying—only six members were absent, and each absentee sent in a satisfactory explanation of his absence. The president of one of the state's institutions of higher learning traveled two hundred miles to attend. The organization of the committee was soon completed. The unanimous choice for chairman was Mr. L. C. Bird, who had shown his ability as general chairman of the Richmond meeting of the American Association for the Advancement of Science in 1938. Dr. Sidney S. Negus, assistant secretary of the academy, was made secretary of the committee as well as of its executive committee. At its first meeting the executive committee set up a number of committees that would encompass most of the suggestions received from the questionnaire.[4]

It was agreed that the academy should capitalize upon the manifest interest of its membership. Obviously, although the half-dozen committees were designed to include most of the topics upon which action was demanded, some topics were almost certain to be sidestepped. Therefore the question put to the scientists and professional leaders who made up the Long Range Committee was: How could such a wide diversification of ideas be unified into one major objective, an objective that would appeal to the entire academy membership and at the same time capture the imagination of the citizens of the state? It was obvious from the nature of the topics suggested that only a project of wide range could elicit the whole-hearted interest of such a group of scientists. Further, if the aims of the academy were to be achieved, the project must have a name with which every one is already familiar, a name that is of significance in the scientific, economic, social and even the romantic life of the state.

[4] A few copies of the minutes of this first meeting as well as those of the executive committee are obtainable from Dr. E. C. L. Miller, secretary-treasurer of the academy.

As every writer knows, finding the right name is sometimes as difficult as writing an article. In our case that name was soon forthcoming[5]—The James River Project, it should be. Careful inspection of the map of Virginia will show that from its westernmost boundary to Chesapeake Bay, the James River transects all the physiographic provinces of the state—the Allegheny Ridges, the Great Valley, the Blue Ridge, the Piedmont and the Coastal Plain. Of the one hundred counties in Virginia, forty-two are either wholly or partially within the James River drainage basin. Most of the other counties have close association with those forty-two. The majority of the educational and research institutions of the state are located within the forty-two counties of the James River Basin. For generations the mighty James was the principal artery of travel of the state; it is renowned in song and story—the Old Man River of a state. The river is as characteristically Virginian as tobacco or peanuts. In this great river we have our unifying idea around which to correlate scientific, sociological and historical research. The project is enormous, being nothing less than the planned study of a large region as a human habitat.

The approach to the problem is essentially twofold. First, there is to be a survey and compilation of what is already known about existing conditions within the area. Secondly, there will be the extension of our knowledge of the region together with the scientific improvement of existing conditions.[6] The first phase of the project, which is to be

[5] At the suggestion of Mr. Justus H. Cline, of Stuarts Draft, Virginia, and a member of the Long Range Planning Committee.

[6] Much of the material that follows is taken, sometimes almost verbatim, from a preliminary statement prepared by Dr. Marcellus H. Stow, who is chairman of the James River Project. A few copies of this statement are available and may be procured by writing Dr. Stow at Washington and Lee University, Lexington, Virginia.

completed during the present year, will attempt to answer such questions as: What is the *present* land-use? What is the *present* status of conservation of mineral resources, of wild life, of forests? What are the *present* conditions of education, of public health, of agriculture, of industry? The second phase, which is to be directed toward the scientific improvement of present conditions, is definitely not a reform movement. The academy will not attempt to put trout in all the mountain streams, but by a scientific study will attempt to determine the conditions under which trout thrive. Instead of a campaign denouncing stream pollution, the academy would undertake a scientific study to determine exactly what constitutes pollution and the means whereby pollution can be avoided, to the mutual benefit of all interests. It is proposed to keep the work on a high plane of scientific research, not becoming involved in the vagaries of politics nor a crusade against "vested interests."

May I again recall that the preliminary survey of the opinion of the academy members revealed the fact that informing the public of the activities of the academy was mentioned more often than any other item except research. This in spite of the inclination of scientists to pursue the even tenure of their way without much regard for what the people think about them or their work. "Research workers are therefore running the risk of becoming isolated from the general mass of the population in our social order," declares Austin H. Clark; and, further, "The history of science—and the varying status of scientific research in the different countries of the world to-day, show us that scientific advance, at least in certain lines, is conditioned by the attitude toward it on the part of the general mass of the population as reflected by their chosen representatives."[7]

[7] Austin H. Clark, THE SCIENTIFIC MONTHLY, 52: 257–260, March, 1941.

In science we will continue to get new facts, new techniques, new principles—these things we can take for granted. What we can not take for granted is the attitude of the people toward the results of science. If science is to prosper the population as a whole must take an interest in and appreciate the work done by scientists. The people can not be asked and will not cooperate just as a favor to scientists but must see in scientific work something of essential value to themselves. The Virginia Academy of Science is determined to take the people of Virginia into its confidence. This is partly the reason why the first major phase of the present experiment will be the publication of a Monograph to be entitled "The James River—Past, Present, Future." This is not being done primarily because it is good policy but because it is the right thing to do.

This monograph, which will be a quarto volume of around six hundred pages, is expected to be published within the year. It will obviously be incomplete, but it should direct attention to the needed fields of investigation and thereby serve as a stimulus for a state-wide undertaking to which scientists and others can contribute. In addition, it should acquaint the non-scientists of the state with the work of their state academy.

In the words of Dr. Stow:

> We wish to present a brief history of the development of these sciences in Virginia, to discuss the contribution that each has made toward the improvement of the region as a Human Habitat, to present and to indicate problems that await initial study or more detailed scrutiny in order to improve the region scientifically, industrially and sociologically. If we may borrow a phrase from the biologists, we wish to make a study of Human Ecology—man's environment—and to ascertain methods of improving it.

Scientists may well inquire as to the reaction of the public to the project. It is still too early to gauge accurately such reaction, but thus far the results have been gratifying. Non-scientists are serv-

ing on the various committees. We have been fortunate in receiving the cooperation of men prominent in science and industry in the compilation of information for the Monograph. "We believe such a monograph, written by competent authorities, will do much toward developing and improving the status of science, industry, and social conditions in the James River Region, and hence in Virginia."

"Essentially there are two types of scientists—one is the fundamental research man who is interested in learning only what happens or what results from a given set of conditions; the other is one who is interested in the application of these fundamentals to the development of processes, methods of manufacture, or creation of new commodities." Both types are essential, but all too frequently the fields of the two are not brought together. It is hoped that the James River Project will do much toward remedying this situation.[8]

Recently in London, England, there was held a very significant conference on "Science and World Order." Much was said at that conference about planning for the future but, as one speaker remarked, planning can never be more than an "administrative convenience" until it is brought into direct contact with human needs. Science may have to reverse certain of its past attitudes. No longer can scientists regard themselves as "mere consultants sitting in remote laboratories," but as active participants in the world of affairs. The human value of science lies in the moral quality of the human purpose directing it. In the words of Edwin Markham:

> We are blind until we see
> That in the human plan,
> Nothing is worth the making, if
> It does not make the man.
>
> Why build these cities glorious
> If man unbuilded goes?
> In vain we build the world unless
> The builder also grows.

[8] Indicative of this new spirit between science and industry it might be mentioned that the Virginia Manufacturers Association invited the Virginia Academy of Science to participate in its annual meeting last October. The academy presented a symposium on the subject, "The Value of Scientific Research to Virginia Industry." Participating in this symposium were: Dr. W. S. Calcott, director, Jackson Laboratory, E. I. du Pont de Nemours and Company; the late Dr. Harrison E. Howe, Editor, *Industrial and Engineering Chemistry*, and Dr. Arthur Bevan, Virginia State Geologist.

SOCIAL CONTINUITIES IN CYPRUS

By Dr. JOHN FRANKLIN DANIEL

THE UNIVERSITY MUSEUM, UNIVERSITY OF PENNSYLVANIA

THE archeologist is often faced with the problem of relating the objects and conditions he discovers on an ancient site with similar manifestations of present-day life. In many regions this involves little more than a feet-on-the-ground attitude, but in a land such as Greece or Cyprus, where there is an unbroken cultural tradition from antiquity to the present day, the problem becomes much more important.

Much has been written, most of it polemic in nature, about the degree of connection between ancient and modern in Greece and the Greek outposts. While scholars are gradually coming to an agreement, the general public has suffered from the vociferous protestations of certain starry-eyed classicists who feel uncomfortable in modern Greece because its inhabitants are human, and resent the fact that there are not glaring white marble statues of the gods on the most striking hill-tops. Adherents of this school argue that the Greek blood has been hopelessly dispersed by repeated invasions of Goths, Slavs, Franks and Turks; that these invasions have reduced the Greek language to a hodge-podge which refuses to follow reasonable linguistic rules; that all intellectual vitality and integrity is gone; and that even the supposed survivals of Greek religion are merely part of a confusing and disgraceful body of superstition.

Fortunately this school has been publicly discredited by the heroic stand of the Greeks in the face of the latest and worst of vandal incursions. The public is now willing to believe, and the best scholars know, that whatever may have happened to Greek blood, Greek character and intellect have lost nothing, and that even the spoken language is no further from that of Plato than Plato himself was from Homer.

The course of events during the last decade finds parallels in the most glorious pages of Greek history. In this war, as so often in the past, the Greeks were torn asunder until almost the last hour by political feuds, in which all took part, and all appeared to be inviting disaster. When, however, disaster appeared, a moratorium was declared on personal animosities, and the entire populace united, even behind a hated dictator, to destroy the common enemy.

The temperamental similarity of the modern Greek to his famed ancestors was evident even before the war. The schoolboy whom I once met on the train, who was going to Athens to complain to the Prime Minister about his village school and who undoubtedly saw him and argued heatedly, was in the best classical tradition. The humor, compounded of ribaldry and politics, of a modern Athenian musical comedy is amazingly like that of Aristophanes.

General observations of character are of use to the field archeologist in more ways than one, but by and large he is concerned with a different aspect of the continuity from antiquity. In many cases he will find it difficult to determine whether an obvious similarity indicates a real generic connection or whether it is merely a coincidence.

While excavating in Cyprus among the remains of a city which was inhabited from 1600 till about 1000 B.C., I was frequently struck by resemblances in detail between the ancient city and the nearby

modern village of Episkopi. The general type of construction of at least the simpler houses of the ancient city was remarkably close to that of the village houses of the present day. In both, the walls averaged about eighteen inches in thickness, and both were built of a superstructure of sun-dried brick laid on a foundation of rough stones a foot or two high. The similarity went even to minor details. The bricks were about eighteen inches square and five or six inches thick in both periods, and both were made with a chaff temper. The ancient bricks often contain small potsherds and other ancient objects, proof that they were made of earth dug within the confines of the city rather than at a suitable clay bed in the country. At the present time in Cyprus some brick is made at factories, but most of it is still produced locally in the villages. The village brick-makers do not have permanent workshops, but move around from one spot to another, making the bricks for each job separately, and as near to the projected house as possible. There is every reason to believe that this practice is the same as in antiquity.

In excavating one house of the twelfth century B.C., I was puzzled by large patches of white clay, pure, save for some carbonized vegetable matter, which lay directly over the ancient floor. The workmen called my attention to the fact that this same white clay is used to-day in waterproofing earth roofs, and even pointed out the only bed in the neighborhood where the material is obtained. Roofs in the modern village are almost flat but have a slight slope to one side to carry off rain water. They consist of beams laid longitudinally across the room, over which is placed a layer of reeds or matting. This is then covered with six to ten inches of ordinary clay, and finally dressed with a thinner layer of the white clay. In view of the other similarities, it seems not unreasonable to suppose that the roofs of the ancient houses were much like those described. The only difference is that the ancient roofs seem to have dispensed with the layer of ordinary clay; the white clay was apparently placed directly over the reeds or mats.

The ancients kept their water, olive oil, wine, grain and many other foods in large storage jars. These jars might be placed on the floor in the corner of the room, or else sunk below the floor with only the rim showing. Another system of storage, used primarily for grain, was to dig a deep hole in the ground, line it with clay, and then light a fire in it which baked the clay, thus keeping the pit clean, rat-proof and relatively dry. Storage jars, similar in both shape and use to those of the early city, are found in almost every village house in Cyprus, and underground clay-lined storage pits are still found in at least one town on the island.

More examples might be mentioned, but these serve to illustrate the marked similarity in conditions in antiquity and now. Any one of these might be a coincidence, for given like needs and like resources, similar results are probable. In this case, however, the large number of similarities argues against coincidence. We know that this region was occupied without any radical break from very early times right down to the present day. There were several migrations from abroad and several foreign conquests, but there is nothing to indicate a complete change of population in connection with any of these. The worst disaster which ever befell the city was the earthquake in the fourth century A.D., as a result of which the classical city was abandoned, and the inhabitants moved to the site of the present village. But even this did not fundamentally affect the race and customs of the inhabitants. There is therefore every reason to believe in a direct continuity in the

ethnic and cultural traditions of the village.

If we are correct in assuming that there is such a continuity, modern village life assumes a new importance for the excavator, who may hope to find explanations of some of his archeological mysteries in the conditions of the present day. This does not mean that one can assume complete identity, or overlook the possibility of gradual, but nonetheless profound changes. For example, in spite of the similarity in architecture and in household appointments, Episkopi is a relatively humble agricultural village, whereas we know that its predecessor was a large and prosperous city and for centuries the capital of a kingdom. Among the ancient ruins we have found objects in gold and ivory such as the modern inhabitants of Episkopi have never hoped to own. When, however, we find in the excavations enigmatic objects of some humble material not mentioned in the text-books, but identical with household objects in use in the village to-day, we are perhaps justified in assuming that the ancient object served the same use as its modern counterpart.

Perhaps more important, and certainly more difficult to trace, than a continuous tradition in the use of certain artefacts, is a survival of certain prejudices and attitudes. One of the minor puzzles of Cypriote archeology is the fact that Cyprus continued to produce pottery laboriously by hand centuries after its neighbors had adopted the use of the potter's wheel. It was long thought that this illustrated a Cypriote resistance to new ideas. We now know, however, that Cyprus did know the potter's wheel by at least 1600 B.C. and used it for certain types of wares while it continued to produce others by hand. It is not until fairly recently that scholars have come to realize that there is an excellent parallel to this in the island to-day, for the most popular type of water jar in Cyprus is still made by hand. Another peculiarity of Cypriote ceramics was the predominance of round bottoms on their vases. Though ring bases were known from a fairly early date, the stability which these offered was not particularly cherished, and the round base reigned supreme for centuries. Most of the water jars, both hand- and wheel-made, in use in the island to-day have round bases. The wheel-made jars are almost identical in shape and fabric with jars used there in the classical period; the hand-made jars practically duplicate a favorite type of the third millennium B.C., with a hand-burnished red slip and incised decoration. The shape is also closely paralleled in the early period. It would be logical to assume that the modern jars are imitations of ancient vases seen in the museum or elsewhere. This is, however, by no means certain, for the modern tradition appears to go beyond the time when archeology might have furnished prototypes.

The fondness for the round bottom may have its basis in the native psychology. In the steaming Cypriote summer a thirsty man wants his drink in a hurry, and a round-bottomed jar is more easily tipped. After being refreshed he is perfectly willing to spend ten minutes re-balancing the jar, particularly so if he is a workman being paid by the hour.

This article has not posed new problems or furnished important new evidence in favor of a view which is in the course of being accepted by scholars. It does, however, try to stress the integral relation between present conditions and those of the more or less remote past. Thus not only the archeologist should make a careful study of modern village life as an aid in his own study of antiquity, but the classicist who is inclined to deprecate the present inhabitants of historic lands, should not forget that even their heroic ancestors were human.

BOOKS ON SCIENCE FOR LAYMEN

DEVELOPMENT OF THE VERTEBRATES[1]

IN this handsome large-octavo volume the University of Chicago Press has added another masterpiece to its science series. In a little over four hundred pages of text and in a remarkably simple and understandable way the author has told the epic story of the rise and branching out of the vertebrates from even before *Amphioxus* to man. The hundreds of illustrations represent the best of their kind in line and half-tone. This work is distinctly not "a little of everything," but a thoroughly integrated mosaic. In the reviewer's experience no other single work has succeeded so brilliantly both in telling the grand story of vertebrate evolution and in holding the mirror of science up for man to see himself as part of that story.

No single human brain could be equally familiar at first hand with the vast fields of paleontology, systematic zoology, embryology, physiology, anthropology, archeology, etc., which have contributed of their best to this work, and the author acknowledges the constant assistance of his former colleagues at the University of Chicago who contributed from the material used in their courses; nor does he neglect the American Museum of Natural History, the New York Zoological Society and many other sources whose treasures of illustrations were freely opened for this work. Joyful cooperation and close checking of the text by the author's wife and others have eliminated errors to such an extent that the reviewer succeeded in noting only one: *i.e.*, the provisional reconstruction of *Plesianthropus*, opposite page 183, is by Gregory and Hellman, from Broom's specimens.

The chapter on the frog is a welcome relief from the dry-as-dust method of the ordinary laboratory manual, partly because it treats anatomy and physiology together. As its topics are arranged in the same order as those in the chapter on human anatomy, the student is advised to compare the two organisms, contrasting their diverse specialization for locomotion and noting the many other ways in which the frog is more primitive than man.

The chapters on human anatomy and anthropology, which take up nearly half the book and in which the influence of Professor Griffiths Taylor is gratefully acknowledged, would form an admirable volume even by themselves but gain greatly by being connected with the general story and with the sections on the mammals, on the origin of the mammals and by the contrast in the basic physiology and anatomy of the various classes.

This book must long retain its leadership for general reading, for careful study and for perspective in diverse branches of biology.

WILLIAM K. GREGORY

[1] *Man and the Vertebrates.* Alfred Sherwood Romer. 3rd edition. Illustrated. viii + 405 pp. $4.75. November, 1941. University of Chicago Press.

THE STORY OF MODERN CHEMISTRY[1]

THE chemical world has long needed a successor to E. E. Slosson's "Creative Chemistry," the phenomenal success of 1918, now out of print. This is it—as interesting a book on the development and present status of the synthetic organic chemical industry as any one can hope to see. Its swift conversational style is almost gossipy in its light touch and in its facile portraiture of scores of

[1] *This Chemical Age.* Williams Haynes. Illustrated. xxxiii + 385 pp. $3.50. 1942. Alfred A. Knopf.

chemical personalities of the nineteenth century and of the present. Yet, quite unobtrusively it is packed with facts and figures on this great industry that are authoritative and precious even to chemists.

It is written from the inside, for Williams Haynes was for years editor of *Chemical Industries*, knows everybody in "the game" and has himself played a prominent part in the meteoric rise of the industry since 1914. But it is written from the inside out, as every good book should be, for the author knows the public as well as he does his colleagues, has a journalist's sense of what the reader does not know and wants to. The result is a book for business men who deal with chemical materials, for economists, lawmakers, and above all for the young man about to choose a career.

There are twenty chapters, all in high gear, a brief bibliography (which is characteristically entitled "If You Want More"), an excellent glossary and a complete, 22-page index. The subjects covered are: dyes, perfumes, "sulfa-" drugs, camphor, rubber, petroleum products, cellulose, rayon, nylon, plastics and a final chapter on war chemicals, including toluol, explosives, nitrates, potash, incendiaries, all as of just before Pearl Harbor. It will in a few years be a precious record of just what we started with on that day. The sub-title, "The Miracle of Man-Made Materials," is correct, except that the full and candid treatment of each subject replaces the apparent miracle in each case by good solid science. The title itself, I regret to protest, is too sweeping, for there is much more in this chemical age than organic synthesis. Even Slosson's less ambitious title included fertilizers, corn products, chemical warfare, the electric furnace, metallurgy, radioactivity, nutrition, vegetable oils and fats. To justify the title would have required a far larger book.

Most commendable is the fact that the "miracles" of industry are not presented as spectacular magic but as the logical outgrowth of many years of painstaking research. The book actually begins with Henry Cavendish and the composition of water. The discussion of dyes begins not with Perkin but with the story of Liebig, way back in 1845, who recommended A. W. Hofmann for a professorship at the Royal College of Chemistry, and who in turn had a student named Tommy Hall, who as instructor at the City of London School later discovered the precocious lad, Perkin. Then the detailed story of the work of 18-year-old Perkin in Hofmann's own laboratory and his tongue-lashing by Hofmann when he left the college for the commercial development of mauve. Step by step the slow fifty-year growth of the industry from that day on to Germany's well-earned dominance is told. A wealth of detail not previously published in book form its evidence of enormous historical research. Supplemented by the author's intimate personal knowledge of the events since 1914, this becomes a valuable source book for chemists and a fascinating biography of the childhood and youth of one of the most powerful factors in our present civilization. One can not but hope that Williams Haynes will be spared to write the history of the maturity of his beloved industry during the next twenty years.

GERALD WENDT

PSYCHOLOGY AND THE PRACTICE OF MEDICINE[1]

IN the past generation the science of medicine and the resulting rise of specialization have sometimes obscured to the physician and surgeon the fact that the patient is a person instead of a mere aggregation of parts. Yet the successful doctor, whether he admits it or not,

[1] *Psychotherapy in Medical Practice.* Maurice Levine. xiv + 320 pp. $3.50. 1942. The Macmillan Company.

is a psychiatrist in the sense that he deals with the patient's personality as well as with his affected organs. Indeed, often the organ complaint may be merely the manifestation of a psychological problem!

Dr. Levine, an experienced and thoroughly trained psychiatrist, presents here a clearly, simply written but comprehensive account of how the general medical man may avail himself for the benefit of his patient of the simple truths of psychiatry. Defining psychotherapy as therapy by psychologic measures, he continues: "By psychologic measures we mean that the treatment is done through the patient as a whole, not through some of the parts of his body. It means that the treatment works through the functions that are associated with his highest integrations, through his speech, his perceptions, his thinking, his emotions, and his relationships with other people and other objects. It means treatment applied directly to the 'mind,' by which we mean not a separate entity, but the functioning of the person as a human being.

"Psychotherapy includes the direct treatment of one person, as a person, by another. It includes also the indirect treatment of one person by another, through the intermediary of other persons or situations. A rearrangement of the patient's family life by the physician is psychotherapy, just as a direct discussion of problems with the patient, is psychotherapy." Beginning with a chapter on Common Misconceptions (such as that heredity is the chief cause of psychiatric disorders, that there is a sharp difference between "normal" and "abnormal," that psychiatric illness is a disgrace, that marriage cures all varieties of psychiatric disorders, that the ideal child is always obedient, for example), he discusses the general Methods of Psychotherapy, Methods for the General Practitioner, Methods for the Specialist, Suicide Risks, The Study of Psychogenic Factors, The Choice of Cases, Sex and Marriage, Basic Attitudes toward Children, The Problems of Parents and Children, and Normality and Maturity.

The volume is so packed with sound advice that it can not well be abstracted; perhaps the reader of this review would not especially care for an abstract. Although the book is designed primarily for medical practitioners, it can be read with profit by the intelligent layman who is interested in psychological medicine. Certainly every physician in practice will profit by a careful perusal of this very useful addition to medical literature.

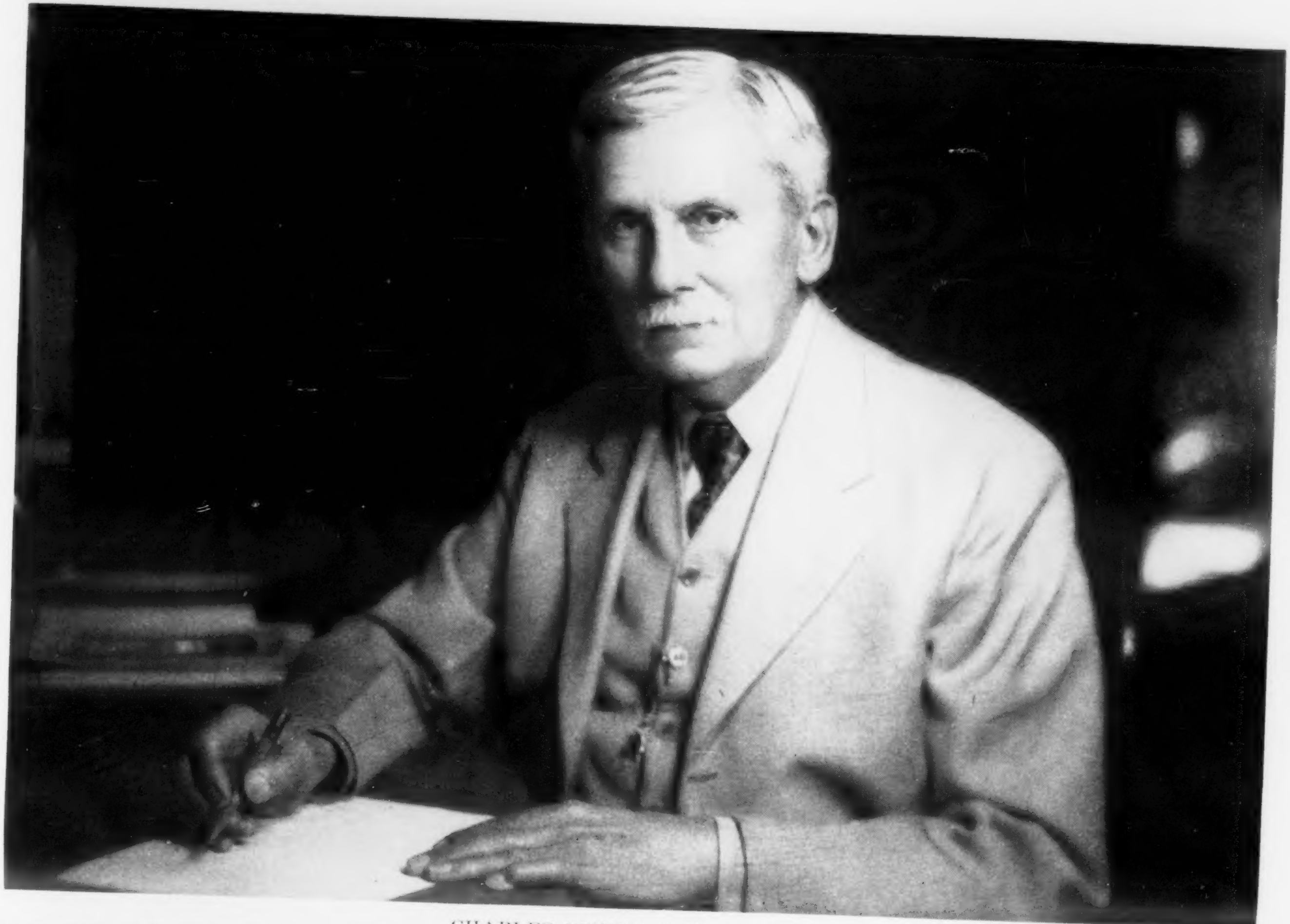
WINFRED OVERHOLSER

A STUDY OF MUSIC[1]

HERE is a comprehensive textbook for students of music, covering musicology, defined by the author as "that branch of learning which concerns the discovery and systematization of knowledge concerning music." It is well documented but has no illustrations. The topics are well chosen, but as a text the book will not go far except in the hands of the teacher who is familiar with sources of the materials. The general reader who is not a specialist in some field of musicology will see in this book a skeletal outline as sketched by a practical musician.

CARL E. SEASHORE

[1] *Introduction to Musicology.* Glen Hayden. xiii + 329 pp. $4.00. 1941. Prentice-Hall, Inc.



CHARLES SCHUCHERT, 1858–1942

THE PROGRESS OF SCIENCE

CHARLES SCHUCHERT, 1858–1942

Professor Charles Schuchert, distinguished paleontologist and stratigrapher and foremost authority on paleogeography, died on November 20, 1942, in New Haven, Connecticut, in his eighty-fifth year. At the time of his death he was seeing through the press the second volume of his great synthesis of North American stratigraphy, due to appear on December 15 of this year, and had nearly finished writing the third and final volume with all the eager keenness and enthusiasm that were so inspiring to those privileged to know him. The photograph of Professor Schuchert here shown, taken at the age of eighty-two, portrays remarkably well the man as we knew him, deeply respected and greatly beloved colleague.

Born in Cincinnati, Ohio, on July 3, 1858, he was destined by the circumstance of his environment to make paleontology his future career. At the age of eight his interest was aroused by a fossil coral casually given to him. This started him collecting the fossils so wonderfully well preserved in the strata exposed in the hills of Cincinnati. His parents did not encourage him to go into paleontology as a profession; in fact, his father often told him that if he paid as much attention to the furniture business as he did to the gathering of fossils he would some day be a rich man. However, as Schuchert long afterwards confessed, making furniture was hard work, but collecting fossils and learning their meaning was "endless pleasure." His father died while the boy was still young, and the future paleontologist on receiving his patrimony of $1,400 spent half of it in enlarging his collection of fossils.

From 1885 to 1888 Schuchert was assistant to Edward O. Ulrich, curator in charge of the Cincinnati Society of Natural History, who was then just beginning the career that made him also one of the foremost paleontologists of his time. From Cincinnati Schuchert went to Albany, New York, to become the personal assistant of the great master of paleontology, James Hall, of the Geological Survey of New York. Hall, whose appetite for acquiring collections of fine fossils was well-nigh insatiable, made the appointment contingent upon Schuchert bringing with him his brachiopods and letting "us have the use of them and his knowledge of them." The new assistant soon proved highly useful because of his great ability and enormous capacity for work. During his stay at Albany he became intimately associated with the brilliant young paleontologist, John M. Clarke.

From Albany Schuchert went to Minneapolis, where he served a short time on the Geological Survey of Minnesota, mainly in preparing a volume on the Brachiopoda. He then became preparator of fossils for Dr. Charles E. Beecher at Yale University. In 1893 he was appointed assistant paleontologist on the U. S. Geological Survey and in 1894 he became assistant curator at the U. S. National Museum, where he remained until 1904. In that year he accepted a call to Yale as professor of paleontology and curator of the geological collections of Peabody Museum and as professor of historical geology in the Sheffield Scientific School, to fill the positions left vacant by the death of Charles E. Beecher. Here he had to make, as he himself has characterized it, "the somewhat painful metamorphosis from curator to professor." The metamorphosis, though it may have been painful, was eminently successful, and he became acting dean of the Graduate School, 1914 to 1916, and chairman of the department of geology from 1919 to 1921.

On reaching the age of sixty-five in 1923, Professor Schuchert decided that in view of the large amount of research work he had in hand he would retire from his teaching and administrative duties. Rich in experience, equipped with an encyclopedic store of information on his chosen fields, and open to all new ideas, Professor Schuchert produced during the two decades after his retirement a great body of work that few younger men can hope to accomplish in the same span of time. It has been a real surprise to many that Professor Schuchert should have accomplished so much in his chosen science and attained such preeminence without the benefit of a college or university training. Perhaps, as has been suggested in somewhat lighter vein, he did not have to learn and unlearn the theories of professors. But, as David White has said, "where could a student have found more satisfying courses in Paleozoic paleontology than under Ulrich, Hall and Clarke, Beecher, and Walcott?"

Professor Schuchert has made outstanding contributions in many branches of geology. In his early years his interests were almost wholly centered in invertebrate paleontology and Paleozoic stratigraphy. His devotion to these subjects never waned, but as time went on his interests broadened more and more to the philosophical aspects of his science. The phylogeny of the Brachiopoda, the climates of the geologic past, the delimitation of the geologic systems, the dating of mountain-making movements and the doctrine of geosynclines are some of these. Transcending all these, however, were his paleogeographic studies and the resulting paleogeographic maps, on which are shown the distribution of land and sea in the geologic past. In 1910 he published his now classic "Paleogeography of North America," in which were shown the distribution of the seas at fifty successive stages in the history of the North American continent. These maps were a notable advance on all earlier attempts, in that far narrower time limits were used than had previously been employed; that is, the boundaries of the seas were shown as they were conceived to have existed at a definite instant (geologically speaking) in the history of North America. Moreover, the correlations were more precise than those previously used. Later the maps were republished in revised and improved form. They now number nearly 125. To the end of his life, Professor Schuchert kept these maps up-to-date by including all new information as it came in. Paleogeographic maps of other continents were drawn. These paleogeographic studies attracted world-wide attention and brought their author international fame. A wholly unexpected outcome of the paleogeographic maps, gratifying to their author, was their wide use by petroleum geologists in the search for oil.

Many honors have come to Professor Schuchert. He was elected to the National Academy of Sciences in 1911. He was president of the Paleontological Society in 1910 and president of the geological Society of America in 1922. The degree of LL.D. was conferred on him by New York University in 1911, the doctorate of science by Yale University in 1930 and the doctorate of science by Harvard University in 1935. The Hayden Gold Medal was awarded to him by the Philadelphia Academy of Natural Sciences in 1929; the Mary Clark Thompson Gold Medal by the National Academy of Sciences in 1934; and in the same year the Penrose Medal of the Geological Society of America, which is conferred "in recognition of eminent research in pure geology" and "of outstanding original contributions or achievements which mark a decided advance in the science of geology." His eminence was also recognized by election to honorary membership in scientific societies in Great Britain, Germany, Austria, Russia, Belgium, Sweden and Norway.

ADOLPH KNOPF

POSTPONEMENT OF THE NEW YORK MEETING OF THE AMERICAN ASSOCIATION

A GREAT meeting of the association was scheduled to be held in New York City during the week beginning on December 28, 1942. Forty-four affiliated societies were expecting to meet with the association. Plans for more than two hundred separate sessions had been nearly completed and nearly two thousand papers were being written. The program was printed and exhibits were being assembled. Then, on a request from the Office of Defense Transportation, the meeting was postponed. It was not postponed to a definite date, because none could be determined with the future depending on the course of the war and its effects upon railway transportation in this country.

Naturally there were disappointments at the sudden change of plans. But scientists realize that greater things than the holding of a scientific meeting are now at stake in the world. The future of science, indeed of freedom, is in the balance. Under these circumstances scientists were willing to forego the pleasures and advantages of attending the meeting and turned their energies to the urgent matters of the day.

Among the general addresses scheduled for delivery at the New York meeting was the retiring address of Dr. Irving Langmuir, who was president of the association during 1941. The subject he had chosen for his address was "Science, Common Sense and Decency," a title which could not fail to arouse the curiosity of all who read it. A second general session was to be that at which the annual Sigma Xi address was scheduled to be delivered by Dean John T. Tate, of the University of Minnesota. The annual Phi Beta Kappa address was to be delivered by the Honorable Dr. Hu Shih,

DR. A. J. DEMPSTER
PROFESSOR OF PHYSICS, THE UNIVERSITY OF CHICAGO; CHAIRMAN OF THE SECTION ON PHYSICS.

DR. JOHN T. BUCHHOLZ
PROFESSOR OF BOTANY, UNIVERSITY OF ILLINOIS; CHAIRMAN, SECTION ON BOTANICAL SCIENCES.

DR. CHESTER R. LONGWELL
PROFESSOR OF GEOLOGY, YALE UNIVERSITY; CHAIRMAN OF THE SECTION ON GEOLOGY AND GEOGRAPHY.

formerly Ambassador from the Chinese Government to the Government of the United States.

Finally, addresses were to be delivered by the retiring vice-presidents of the association; there is a vice-president for each of the fifteen sections under which its work is organized and of which they are the respective chairmen. Their addresses, too, were postponed, but it is hoped that arrangements will be made for their publication even though they can not be delivered as planned. The vice-presidents are among the most eminent scientists in their respective fields and their addresses are correspondingly worthy of attention. The presidents of most of the affiliated societies intending to meet with the association were also scheduled to deliver their retiring addresses, but their voices were stilled by the postponement of the meeting and they must deliver them at some local meeting or resort to publication without oral presentation.

DR. HUGH S. TAYLOR
DAVID B. JONES PROFESSOR OF PHYSICAL CHEMISTRY, PRINCETON UNIVERSITY; CHAIRMAN OF THE SECTION ON CHEMISTRY.

DR. W. C. ALLEE
PROFESSOR OF BIOLOGY, THE UNIVERSITY OF CHICAGO; CHAIRMAN OF THE SECTION ON THE ZOOLOGICAL SCIENCES.

With so many casualties due to an action that came as suddenly as the attack on Pearl Harbor, it might be supposed that the association and its affiliated societies are in a state of considerable confusion. However, such is not the case. Scientists should have, and do have, stabilities acquired from their studies of the world of nature about them. They do not doubt that present storms will pass away and that spring will come again. They are sure, similarly, that the cold hatreds now hardening the hearts of men will eventually melt into the human kindness that has existed in every age and among every people. They look forward with confidence to the time when they can work again directly for the welfare of all their fellow men.

Although the view of distant goals that science gives maintains the courage, the tasks at hand must be carried out under existing conditions, and they are far different from those for which scientists long. The demands of war have

DR. HAROLD HOTELLING
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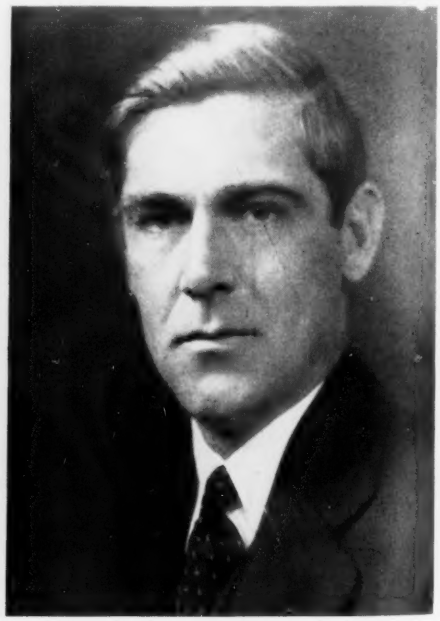
DR. HENRY E. GARRETT
ASSOCIATE PROFESSOR OF PSYCHOLOGY, COLUMBIA UNIVERSITY; CHAIRMAN OF THE SECTION ON PSYCHOLOGY.

DR. MORRIS R. COHEN
PROFESSOR OF PHILOSOPHY, THE UNIVERSITY OF CHICAGO; CHAIRMAN OF THE SECTION ON HISTORICAL AND PHILOLOGICAL SCIENCES.

compelled scientists in every field, for example, the vice-presidents of the association whose portraits are reproduced on these pages, to lay aside the investigations on which they have been engaged to take up others of immediate and urgent importance. Laboratories have lost largely of their staffs and been greatly depleted of their equipment. The routines of the lives of individuals have been interrupted, hours for rest have been greatly reduced, recreation and relaxation are disappearing, normal home life has been broken, the leisure for reflection that has always been deemed essential no longer exists—yet, with very few exceptions, scientists have risen to new heights of productivity under these supposedly adverse conditions without suffering any serious ill effects. Perhaps many of the luxuries of life are more harmful than beneficial, because the human organism and the human mind have not yet learned how to use them advantageously, or perhaps have not yet acquired a tolerance for them. If this is true, science in the near future should set new goals for attainment, goals that on the physical level include higher ideals of perfection, goals that on the intellectual level include broader acquaintance with nature and man, and goals that on the moral level make the apparent interests of the individual inferior to the interests of the whole. Perhaps it requires the shocks of war to teach what should be obvious, both from human history and through reason.

In spite of present disruptions, scientists have no fears that the importance of science will decline in the world. On the contrary, they confidently expect that after the close of the war it will have its greatest period of activity, and that then it will render its greatest service to mankind because careful attention will be

DEAN W. R. WOOLRICH
PROFESSOR OF MECHANICAL ENGINEERING, UNIVERSITY OF TEXAS; CHAIRMAN OF THE SECTION ON ENGINEERING.



DR. WADE W. OLIVER
PROFESSOR OF BACTERIOLOGY, LONG ISLAND COLLEGE OF MEDICINE; CHAIRMAN OF THE SECTION ON MEDICAL SCIENCES.

DR. A. E. MURNEEK
PROFESSOR OF HORTICULTURE, UNIVERSITY OF MISSOURI; CHAIRMAN OF THE SECTION ON AGRICULTURE.

DR. HAROLD F. CLARK
PROFESSOR OF EDUCATION, TEACHERS COLLEGE, COLUMBIA UNIVERSITY; CHAIRMAN OF THE SECTION ON EDUCATION.

given to directing it to such ends. Scientific societies, of which there are nearly a thousand—large and small—in the United States alone, will meet again to discuss the progress and the problems in their respective fields; the association in cooperation with its affiliated societies will again present on its programs speakers of national and international reputations, and will hold scores of different sessions for reports on explorations into nearly every subject of human interest.

F. R. Moulton,
Permanent Secretary

ANOTHER STELLAR EXPLOSION

The brightest "new" star, or nova, seen for more than a generation has recently flared up in the southern constellation of Puppis. Professor B. H. Dawson, of La Plata, Argentina, reported his discovery to the Cordoba Observatory, whence the discovery was immediately cabled to Harvard on November 10. By November 12 the new star reached its maximum light, at magnitude 0.5, and shone for a day or two as one of the ten brightest stars in the entire sky. Many observers, of course, discovered Nova Puppis independently. Such a bright object will be detected by keen-eyed observers in spite of its adverse location as seen from northern latitudes; for New England the maximum altitude above the horizon was only about twelve degrees around 5 or 6 A.M.

The nova problem is still an outstanding riddle in astronomy. Hence the occurrence of an unusually bright nova is of great value because the most powerful spectrographic equipment may be utilized in its study. Nova Puppis, how-

REGION OF NOVA PUPPIS BEFORE THE OUTBURST
THE SMALL WHITE ARROW INDICATES THE POINT WHERE THE NOVA APPEARED.

ever, demands attention for still another reason. It appears to be a *hybrid*, intermediate in class between the ordinary novae and the supernovae. An inspection of older Harvard photographs taken at the South African station reveals no trace of a stellar image in the position of the sky now occupied by Nova Puppis. The nova, therefore, increased in brightness by at least a factor of a few million times, how much more we can not say. Ordinary novae flare up in brightness by a factor of a hundred thousand times, more or less, while for supernovae the increase is not certainly known but may be of the order of a hundred million times.

The light curve of Nova Puppis, on the other hand, is more typical of an ordinary nova than of a supernova. The brightness fell at an average rate of about a third of a magnitude per day for the first two weeks after maximum light. Most supernovae decrease in brightness more slowly than this, while some novae decrease more slowly and others more rapidly. In any case, Nova Puppis faded below naked-eye brilliancy in early December and will continue to fade for many months or a few years. Large telescopes will probably be required for its observation by the time that its light becomes constant. The above-mentioned observations of brightness were made by the American Association of Variable Star Observers and compiled by Mr. Leon Campbell.

The explosional velocities shown spectrographically by Nova Puppis are normal for ordinary novae. Professor Dean B. McLaughlin, of the University of Michigan, reports expanding shells of hydrogen and ionized iron, titanium and magnesium with velocities of the order of 500 miles per second. The expansional

NOVA PUPPIS AS IT APPEARED NEAR ITS MAXIMUM LIGHT

velocities for supernovae appear to be of the order of 3,000 miles per second.

From studies of previous novae, such as Nova Herculis, which in 1934 became nearly as bright as Nova Puppis, or Nova Aquilae, which in 1918 became even brighter, we may visualize the explosion as follows: for reasons unknown a star like the sun in brightness but not in character suddenly blows off its outer atmosphere. The expanding gases, consisting of ordinary metals and gases, remain opaque at a surface temperature of some 10,000° K until they have traveled the order of the earth's distance from the sun. Maximum light occurs near this time, only a very few days after the outburst. Then the expanding layers or shells become increasingly transparent and rarefied as the total light falls. At the same time the exceedingly hot but relatively small nucleus of the star heats these rarefied gases and raises them to higher stages of ionization until we can observe no continuous spectrum but only the bright-line spectrum, essentially fluorescent as in a planetary nebula.

Sometimes these tenuous envelopes can be seen directly as nebulous clouds moving slowly away from the star. Finally, after several years, only the faint (but hot) star remains visible, apparently in its pre-nova condition, little affected by the loss of probably a few earth masses of material.

We may well hope that Nova Puppis, whose recently observed explosion probably occurred some thousands of years ago, will provide some key as to the cause of its outburst. Did the star become internally unstable as it radiated away its store of energy, or did some external mechanism such as a planetary or stellar collision set off or produce the explosion?

FRED L. WHIPPLE

NEWTONIA AT BABSON PARK

SIR ISAAC NEWTON, who was born on Christmas in 1642, lived in London from 1710 until 1725, two years before his death. This was the period of his life in which he was at the height of his fame and the recipient of universal homage and many honors. His London home contained his choicest possessions—library, pictures, medals and numerous documents in his own handwriting.

Good fortune and the vision and initiative of Mrs. Roger W. Babson have secured for America the actual fore parlor of Newton's London House, together with original books from his library, manuscripts, furniture and other memorabilia. They are in the library of Babson Institute, located at Babson Park, a suburb of Boston.

The good fortune consists, in part, of the fact that Newton's house was preserved until 1913 and, in part, of the fact that as it was about to be demolished it was removed and preserved by English antiquarians. Then, in 1937, Mrs. Babson while on a visit to England learned of its existence and at once purchased the fore parlor and arranged for its removal to its permanent house in the library of Babson Institute, which was dedicated in October, 1939. This library now contains all the editions of the works of Newton and their translations, collected by Mrs. Babson during many years of travel and research, original books and documents from his library, material and memorabilia relating to his life and times, and the actual room in

THE RESTORATION OF THE FORE PARLOR OF NEWTON'S HOME
A COPY OF A PAINTING OF NEWTON BY J. VANDERBANK HANGS ABOVE THE FIREPLACE. THE DESK, CHAIRS AND TABLE ARE EXACT REPRODUCTIONS OF ONES WHICH NEWTON USED.

THE HOME OF SIR ISAAC NEWTON

which he worked during his residence in London.

It is believed that Newton's house was built shortly after the Great London Fire in 1666. The restoration of the fore parlor contains the original warm English pine, now mellowed with age; across its threshold fell the shadows of Halley and Locke and Sir Christopher Wren. Here also came Addison and Swift and other English and foreign men of learning and letters. Here are faithful reproductions, made from inventories and careful drawings and descriptions, of the desk at which Newton sat and corrected the manuscripts of the later editions of the immortal "Principia," and of other pieces of furniture. Here are chairs such as those his visitors occupied while they discussed with him questions of science or problems of state.

Thus into the Babson Institute library in the town of Wellesley, located in what was the *new* England of Newton's day has gone this ancient room. At its dedication the library came into possession of a cultural heirloom which can never be duplicated. Its quiet and scholarly walls have held the words of famous men of one of England's most brilliant periods.

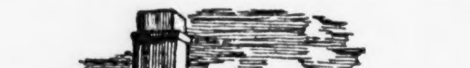
Historical societies of individual admirers of Newton may set up other memorials of Newton. They may be more resplendent, but this venerable room enshrines the memories of the last days of the greatest scientific genius of the English people.

It is particularly significant, therefore, that in this year 1942 when the whole civilized world is trying to roll back the tide of barbarism and savagery that threatens to engulf us, we should pause and consider the life of this man who was born three hundred years ago. He offers us a hope that man can survive and go on to greater wisdom and higher things—and offers us that hope at a time when the outlook for mankind is dark indeed.

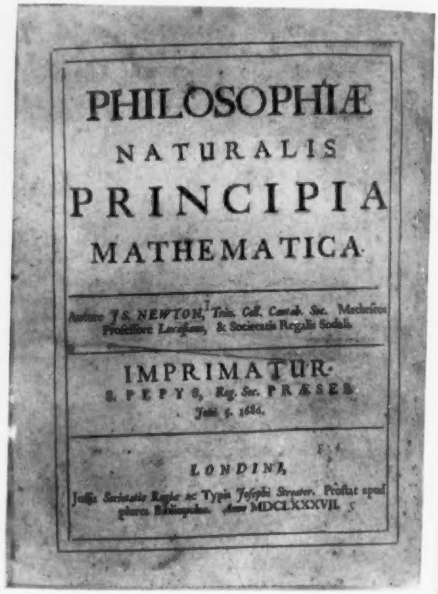
Of the great works of Newton, the

NEWTON EXPERIMENTING
WITH THE COMPOSITION OF LIGHT.

Babson collection includes nearly all editions. It has all the editions of the "Principia," including the scarce second issue of the first edition. One copy of the first edition has notes in Newton's handwriting. There is also a third edition with wide margins, specially bound in red morocco with hand-tooled gold decoration on the cover. This was prepared especially by Newton in his latter years for presentation to the leading scientists and mathematicians in England and on the Continent. There were only twelve copies of this edition and only seven of them are now known to be in existence. Most of the translations and commentaries are in the collection.



NEWTON'S LAST LONDON RESIDENCE
AT ST. MARTIN'S STREET, LEICESTER SQUARE.



PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA.

Autore J S. NEWTON, Trin. Coll. Cantab. Soc. Matheseos Professore Lucasiano, & Societatis Regalis Sodali.

IMPRIMATUR.
S. PEPYS, Reg. Soc. PRÆSES.
Julii 5. 1686.

LONDINI,
Jussu Societatis Regiæ ac Typis Josephi Streater. Prostat apud plures Bibliopolas. Anno MDCLXXXVII.

TITLE PAGE, NEWTON'S "PRINCIPIA" PHOTOGRAPHED FROM A COPY OF THE FIRST EDITION, PUBLISHED IN 1687, NOW IN THE BABSON LIBRARY.

The collection has the edition of 1736 translated from the original Latin by John Colson. It also has the translation of 1737 by an unknown translator, and the French translation of 1740. It also includes Raphson's "History of Fluxions," published in London in 1715, in Latin.

All editions of "Opticks," both En-

glish and Latin, are in the collection; a second edition was in Newton's library and it contains addenda and corrections in his handwriting. It also includes Coste's and Marat's translations into French. Included are "Optic Lectures Read in the Public Schools of the University of Cambridge" by Newton and translated into English from the original Latin in 1728. Papers by Sir Isaac printed in the *Philosophical Transactions* of the Royal Society of London are included.

Many an American has stood with bowed head before the tomb of Newton, in Westminster Abbey, where lie buried the noblest and greatest English dead, and has read with awe and reverence its inscription (in free translation from the Latin), "Mortals, congratulate yourselves that so great a man has lived for the honor of the human race." In the library of Babson Institute a much larger number of Americans will be inspired by the sight of the very room in which Newton lived and worked during the most honored years of his life.

C. J. H.

IN THE BEGINNING

PERHAPS the most interesting by-product of the theory of the expanding universe, a theory which Dr. Hubble has discussed from the observational point of view in his article appearing in this issue, has been the conclusion that the physical universe had its origin some two billion years ago. This is putting Creation back far beyond the period of six thousand years in which most good men believed until within about two generations; and far beyond the fifty or sixty million years for the age of the earth as the maximum permitted by Lord Kelvin and other physicists until this century was well on its way.

The argument for the origin of the physical universe about two billion years ago is about as follows. The spectral lines of very distant stellar systems are found by observation to be displaced from their normal positions toward the red end of the spectrum by amounts that are proportional to the distances of the objects from which the light came. Such displacements of spectral lines would be produced by the recession of the sources of light relative to the receiver. Hence the observed displacements find an explanation in the theory that the galaxies of stars are receding from one another with relative velocities that are proportional to their distances apart.

Accepting this as the correct and only possible explanation of the observations, it follows that on looking backward in time we find these great aggregations of stars progressively nearer and nearer to one another, and that about two billion years ago these myriads of galaxies, each consisting of hundreds of millions or billions of suns, were crowded into a space no larger than that now occupied by our own stellar system. Then what? As we go backward in time was the space occupied by the physical universe ever smaller and smaller and the average density of matter ever greater and greater, the former approaching zero and and the latter infinity? No! That pathway has not been followed by those who have been interested in these phenomena. As men have often done in the past, they escaped unanswered and unanswerable questions and secured peace of mind by inventing a Beginning, a Creation.

By this invention peace of mind has been secured, but only for a moment and at a high price. It has been only for a moment because Dr. Hubble, who discovered the phenomenon we are considering, found on a recent and more critical

and exhaustive examination of the observations on which the bizarre conclusion of the "exploding universe" was based that the data are not exactly in harmony with the theory that the displacements in the spectral lines are due to velocities of recession that are proportional to the distances of the radiating aggregations of stars. Unless further investigations disprove Dr. Hubble's conclusions, the peace of mind afforded by the invention of a Beginning is lost. It deserves to be lost because it was won at the price of ignoring the possibility of other explanations of the observed displacement of the spectral lines of distant galaxies. It deserves to be lost because scientists need to be taught over and over again by experience the lesson that the whole history of science should teach, namely, that they should always be alert for many different interpretations of phenomena, for finality is never reached.

There is, in a sense, a complementary theory to that of Creation, namely, the theory that the universe is doomed to final stagnation and death. Certainly the stars and other luminous bodies are pouring their energy out into space at the expense of their masses. Although the wasting away of a star's mass by radiation is a very slow process in terms of human or even geological history, yet so far as can be seen at present it goes on relentlessly and is never generally reversed. Hence both energy and mass are being scattered through the vast abysses of intergalactic space which light can traverse only in millions and hundreds of millions of years. As the scattering goes on it takes place ever more and more slowly with the result that it will never be completed, though that end is always being approached. In this respect it is different from Creation which, according to the theory under consideration, began with an explosion of a cosmic scale. It should be remarked, however, that if the mass of the universe is infinite no eternal night need everywhere follow, though it is not easy to show precisely why not. Moreover, it is quite likely that open and penetrating minds will discover many other possibilities not now dreamed of.

It is a strange characteristic of the scientist, as well as of the unreflecting, that he often, perhaps generally, finds comfort in the belief that there was a definite beginning, and often in the belief also that there will be an end, of the physical universe; but he clings to a faith that there is within him some immortal spark that will never fade and pass away. There have of course been many exceptions; indeed, nearly two thousand years ago the Roman poet-philosopher Lucretius, in *De Rerum Natura*, thus questioned this faith, according to the rendering of Mallock:

What! Shall the dateless worlds be blown
Back to the unremembered and unknown,
And this frail Thou—this flame of yesterday—
Burn on, forlorn, immortal, and alone?

F. R. M.